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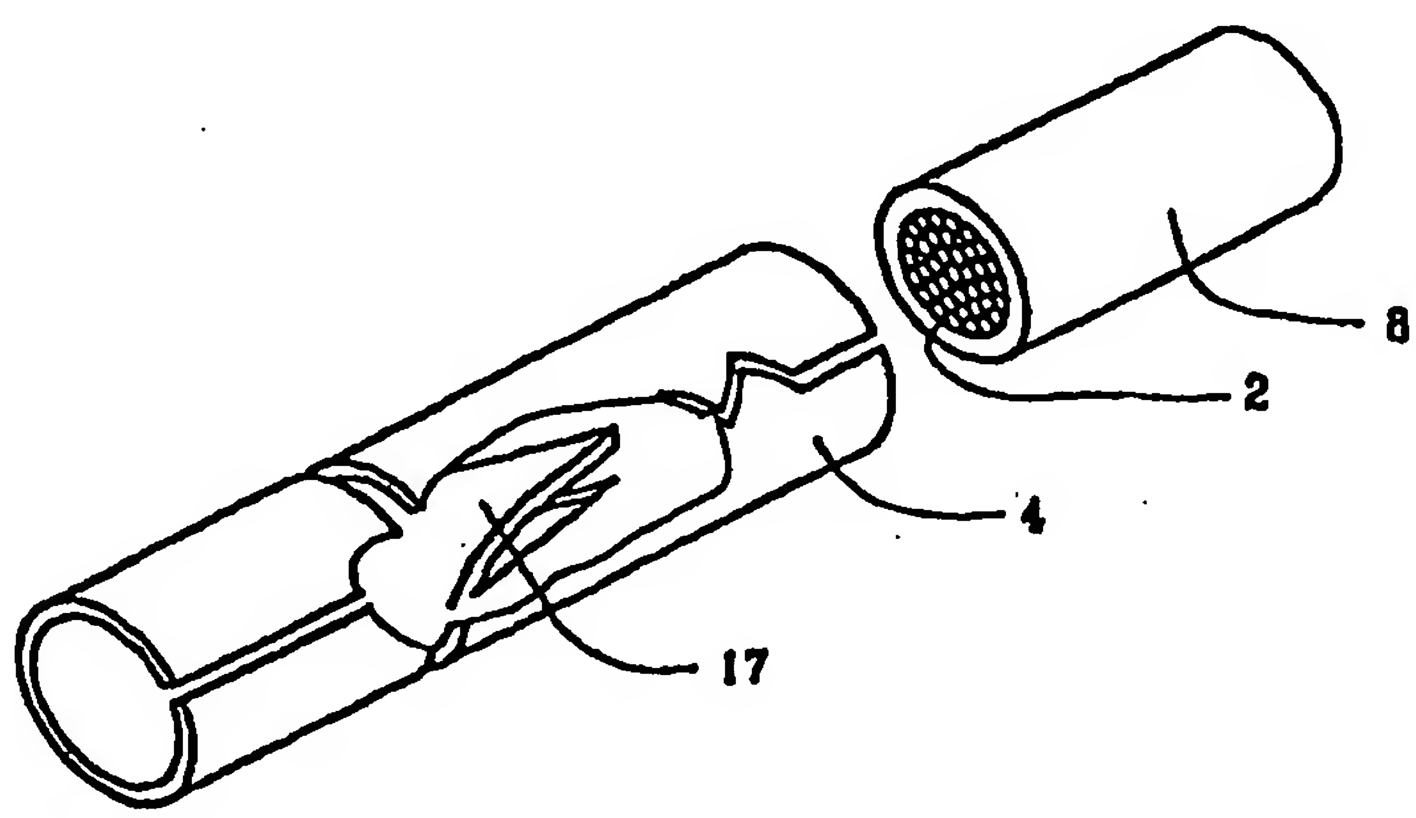
(54) Title: MULTI-CONDUCTOR SOFT HEATING ELEMENT

(57) Abstract

A soft heating element (1) utilizing individually insulated electrically conductive carbon (6) or metal containing threads/fibers of metal wires that are woven together with nonconductive threads, into sheets, sleeves or strips. The individually insulated conductive threads/fibers or metal wires (2) can be laminated between layers of nonconductive insulation (14). Nonconductive polymer insulation (14) can be extruded around the non-insulated electrically conductive threads/fibers or metal wires to form strips, sheets or sleeves/pipes. The electrode conductors (9) are attached to said heating element core (1), which is connected in parallel or in series. The heating element core (1) is shaped in a desired pattern. The thermostats (105) are located in areas of folds in order to control their cycling. When dictated by the heating element design, the electrically conductive threads/fibers have a polymer base, which acts as a Thermal-Cut-Off (TCO) material at predetermined temperatures.



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MULTI-CONDUCTOR SOFT HEATING ELEMENT

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates to soft and flexible electrical heaters, and particularly to heating elements, which have soft and strong metal or carbon containing electrically conductive core and threads/fibers.

2. Description of the Prior Art

Heating elements have extremely wide applications in household items, construction, industrial processes, etc. Their physical characteristics, such as thickness, shape, size, strength, flexibility and other characteristics affect their usability in various applications.

Numerous types of thin and flexible heating elements have been proposed. For example, U.S. patent 4,764,665 to Orban et al. discloses an electrically heated fabric for use in gloves, airfoils and aircraft parts. In this patent the fabric is metallized after being formed in a glove structure, following weaving or arranging in a non-woven format. Copper bus bars are utilized for introduction of electrical current to the metallized textile. Having been made of a solid piece of fabric with metallized coating, this heating element doesn't allow for flexibility in selection of desired power density.

The metallizing of the formed heating element results in a loss of significant economies of scale, only a small number of embodiments can be achieved, thus severely limiting the potential application of this invention. The '665 design is also

not conducive to tight hermetic sealing through the heater areas (no gaps inside), which can cause a short circuit through puncture and admission of liquid into the body of heating element. This element can not be used with higher temperatures due to the damage caused to the polyaramid, polyester or cotton metallized fabric, described in the invention.

Another prior art example is U.S. patent 4,713,531 to Fennekels et al. Fennekels et al. discloses a sheet textile structure combined with resistance elements. These resistance elements comprise metallic fibers or filaments with a denier like that of natural or synthetic textile fibers, and with overall cross sectional thickness of 8 to 24 microns. The '531 design suffers from the following drawbacks: being a sheet product, it is not conducive to hermetic sealing through the body of the heater (no gaps inside), only perimeter sealing is possible, which can result in a short circuit due to puncture and admission of liquid into the body of the heating element; yarns, comprising metal fibers, lack consistency of electrical resistance per given length, and their stretching, compression, or both, will result in very wide fluctuations in resistance, thus limiting the use of this technology in embodiments controlled by strict design and where an uncontrollable power output and temperature variability are unacceptable; yarns are very heavy: from 1 to 7 grams per 1 meter of yarn; the use of silver fibers makes these yarns very expensive; individual conductors have a large cross sectional thickness, each having an outer sheath of braided textile or elastomer.

Another prior art example is U.S. patent 4,538,054 to de la Bretoniere. The heating element of de la Bretoniere'054 suffers from the following drawbacks: its manufacturing is complex requiring weaving of metal or carbon fibers into non-conductive fabric in a strictly controlled pattern; the use of the metal wire can result in

breakage due to folding and crushing and it affects softness, weight and flexibility of the finished heater; it can not be manufactured in various shapes, only a rectangular shape is available; only perimeter sealing is possible (no gaps inside), which can result in a short circuit due to puncture and admission of a liquid into the body of the heating element; the method of interweaving of wires and fibers does not result in a strong heating element, the individual wires can easily shift adversely affecting the heater durability; the fabric base of the heating element is flammable and may ignite as a result of a short circuit; it is not suitable for high temperature applications due to destruction of the insulating weaving fibers at temperatures exceeding 120°C.

A heating element proposed by Ohgushi (US 4,983,814) is based on a proprietary electroconductive fibrous heating element produced by coating an electrically nonconductive core fiber with electroconductive polyurethane resin containing the carbonatious particles dispersed therein. Ohgushi's manufacturing process appears to be complex; it utilizes solvents, cyanates and other toxic substances. The resulting heating element has a temperature limit of 1000°C and results in a pliable but not soft heating element. In addition, polyurethane, used in Ohgushi's invention, when heated to high temperature, will decompose, releasing very toxic substances, such as products of isocyanide. As a consequence, such heating element must be hermetically sealed in order to prevent human exposure to toxic offgassing. Ohgushi claims temperature self-limiting quality for his invention, however "activation" of this feature results in the destruction of the heater. He proposes the use of the low melting point non-conductive polymer core for his conductive fabric-heating element, which should melt prior to melting of the conductive layer, which uses the polyurethane binder with the melting point of

1000°C. Thus, the heating element of Ohgushi's invention operates as Thermal Cut Off (TCO) unit, having low temperature of self-destruction, which limits its application.

U.S. patent 4,149,066 to Niibe et al. describes a sheet-like thin flexible heater made with an electro-conductive paint on a sheet of fabric. This method has the following disadvantages: the paint has a cracking potential as a result of sharp folding, crushing or punching; the element is hermetically sealed only around its perimeter, therefore lacking adequate wear and moisture resistance; such an element can't be used with high temperatures due to destruction of the underlying fabric and thermal decomposition of the polymerized binder in the paint; the assembly has 7 layers resulting in loss of flexibility and lack of softness.

US patent 5,861,610 to John Weiss describes the heating wire, which is formed with a first conductor for heat generation and a second conductor for sensing. The first conductor and a second conductor are wound as coaxial spirals with an insulation material electrically isolating two conductors. The two spirals are counter-wound with respect to one another to insure that the second turns cross, albeit on separate planes, several times per inch. The described construction results in a cable, which has to be insulated twice: first, over the heating cable and second, over the sensor cable. The double insulation makes the heating element very thick, stiff and heavy, which would be uncomfortable for users of soft and flexible products such as blankets and pads. The described cable construction cannot provide large heat radiating area per length of the heater as it would be possible with strip or sheet type of the heating element. The termination with electrical connectors is very complicated because of stripping of two layers of insulation. In addition, in the event

of overheating of a very small surface area of the blanket or pad (for example several square inches), the sensor may fail to sense very low change in total electrical resistance of the long heating element. Such heating cable does not have Thermal-Cut-Off (TCO) capabilities in the event of malfunction of the controller.

Another prior art example is U.S. patent 4,309,596 to George C. Crowley, describing a flexible self-limiting heating cable, which comprises two conductor wires separated by a positive temperature coefficient (PTC) material. Said heating wires are disposed on strands of nonconductive fibers coated with conductive carbon. This method has the following disadvantages: (a) the wires are enveloped and separated by the tough PTC material which thickens and hardens the heating element (b) the distance between the wires is very limited, due to a nature of the PTC material having a high electrical resistance, this prevents manufacturing of heaters with large heat radiating surface; (c) the heater is limited only to one predetermined highest temperature level, therefore, this heating device is unable to bypass said temperature level when a quick heating at the highest temperature is needed.

The present invention seeks to alleviate the drawbacks of the prior art and describes the fabrication of a heating element comprising metal microfibers, metal wires, metal coated, carbon containing or carbon coated threads/fibers, which is economical to manufacture; does not pose environmental hazards; results in a soft, flexible, strong, thin, and light heating element core, suitable for even small and complex assemblies, such as handware. A significant advantage of the proposed invention is that it provides for fabrication of heating elements of various shapes and sizes, with predetermined electrical characteristics; allows for a durable heater, resistant to kinks and abrasion, and whose electro-physical properties are unaffected

by application of pressure, sharp folding, small perforations, punctures and crushing. A preferred embodiment of the invention consists of utilizing of metal and carbon coated synthetic textile threads having a Thermal Cut Off (TCO) function to prevent overheating and/or fire hazard.

SUMMARY OF THE INVENTION

The first objective of the invention is to provide a significantly safe and reliable heating element which can function properly after it has been subjected to sharp folding, kinks, small perforations, punctures or crushing, thereby solving problems associated with conventional flexible heating metal wires. In order to achieve the first objective, the electric heating element of the present invention is comprised of insulated electrically conductive threads/fibers or metal wires. The conductive threads/fibers may be made of carbon, metal microfibers, textile threads coated with metal, carbon, conductive ink, or their combination. The proposed heating element may also comprise metal wires and their alloys. The conductive threads/fibers possess the following characteristics: (a) high strength; (b) high strength-to-weight ratio; (c) softness; (d) flexibility; (e) low coefficient of thermal expansion. The heating element core described in this invention is comprised of electrically conductive strips, sleeves, sheets, cables, rope of strands of thread/fibers, which radiate a controlled heat over the entire heating core surface.

A second objective of the invention is to provide maximum flexibility and softness of the heating element. In order to achieve the second objective, the electric heating element of the invention contains thin (.01 to 3.0 mm, but preferably within the range of 0.05-1.0 mm) individually insulated conductive threads/fibers or metal

wires, which are woven or stranded into continuous or electrically connected strips, sleeves/pipes, cable, sheets or bundles. This arrangement may be arranged and insulated to have gaps between the electrically conductive media. Another preferable configuration consists of extruding soft insulating material, such as, but not limited to PVC, polyurethane, temperature resistant rubber, cross-linked PVC or polyethylene around a multitude of conductive thread/fiber or wire electrical conductors provided that said electrical conductors are separated by said insulating material.

A third objective of the invention is to provide for the uniform distribution of heat, without overheating and hot spots, thereby solving the problem of overinsulation and energy efficiency. In order to achieve this objective, (a) conductive threads in the heating elements are separated by non-conductive fibers/yarns or insulating polymers, (b) one side of the heating element may include a metallic foil or a metallized material to provide uniform heat distribution and heat reflection. It is also preferable that the soft heating elements of the invention are made without thick cushioning insulation, which slows down the heat delivery to the surface of the heating unit.

A forth objective of the invention is to provide for ease in the variation of heating power density, thereby solving a problem of manufacturing various heating devices with different electric power density requirements. In order to achieve the forth objective, the electroconductive threads/yarns, fibers or metal wires are first insulated by polymer, creating multiple thin cables, which then laminated between woven or non-woven fabric, or interwoven with nonconductive threads into strips, sleeves/pipes or sheets with predetermined width, density of weaving and thickness. It is preferable that the strips and sleeves/pipes, sheets are made of combination of threads/fibers with different electrical resistance and/or include electrically

nonconductive high strength polymer or inorganic (such as refractory ceramic or fiberglass) fibers.

A fifth objective of the invention is to provide a high level of temperature control. In order to achieve the fifth objective, at least one of the following is applied: (A) at least one thermostat is wrapped by the heating element or located in the place of multiple folding of the heating element core; (B) at least one of conductive threads or wires, running through the whole length of the heating element is connected to an electronic device operated by a change of electrical resistance, caused by the integral temperature change in the sensor.

The sixth objective of the invention is to provide a high level of safety, minimizing possibility of fire hazard. In order to achieve the sixth objective: (A) multiple thin conductive cables are reinforced by strong and flame retardant threads/fibers, and (B) the conductive media of the heating cables may comprise metal or carbon containing textile polymer threads/fibers having melting point from 120oC to 300°C. The melting of the conductive threads/fibers results in breaking of electrical continuity in the heating system. Thus the proposed heating elements can operate as a high temperature fuse or TCO (Thermal-Cut-Off) device.

A seventh objective of the invention is to provide for ease in manufacturing of the heating element core, thereby eliminating a problem of impregnation of the whole fabric with stabilizing or filling materials to enable cutting to a desired pattern. In order to achieve the fifth objective, all strips, sleeves/pipes, sheets, ropes and threads are assembled into a desired stable shape prior to the heating element manufacturing.

A eighth objective of the invention is to provide a temperature self-limiting properties to the heating element core if dictated by the heater design thereby

eliminating a need for thermostats. In order to achieve the sixth objective, the positive temperature coefficient (PTC) material is utilized in the selected areas of the heating element core.

In one embodiment, the present invention comprises a heating element containing soft, strong and light electrically conductive threads/yarns acting as conducting media. The heating element is also highly resistant to punctures, cuts, small perforations, sharp folding and crushing. It can be manufactured in various shapes and sizes, and it can be designed for a wide range of parameters, such as input voltage, desired temperature range, desired power density, type of current (AC and DC) and method of electrical connection (parallel and in series). A heating element preferably consists of non-conductive fibers/yarns and electrically conductive metal or carbon containing threads/yarns woven into, embroidered on, laminated between or stranded into strips, ropes, sleeves/pipes, sheets or strands of threads.

The selected areas of the heating element core may contain highly conductive metal coated threads to provide redundant circuits in the heater. The heating element core may include a positive temperature coefficient (PTC) material to impart temperature self-limiting properties. The heating element core is shaped by folding or assembling of said conductive media into a predetermined pattern. The electrodes are attached to said heating element core and are electrically connected in parallel or in series. The soft heating element core is sealed to form an assembly containing at least one electrically insulating layer which envelops each strip, rope, sleeve/pipe, sheet or strand of threads.

The selected areas of the heating element core may also contain electroconductive threads or wires to provide sensing of resistance/current change

caused by variation of the heat. The heating element core is shaped by folding or assembling said individually insulated conductive media into a predetermined pattern. The electrodes are attached to said heating element core and are electrically connected in parallel or in series. In the event of utilizing an alternating current, the individually insulated cables in the heating element core may be connected in such a way as to minimize electromagnetic field (EMF). The following are some of the methods for reducing/eliminating EMF in the preferred embodiments of the invention:

(a) Utilizing of the voltage step-down transformer;

(b) Utilizing of the voltage step-down transformer and rectifier;

(c) Utilizing of the AC rectifier with filtering capacitor;

(d) Providing of simultaneous opposite current flow in the individually insulated cables of the heating element core.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a plan view of the heating element core electrically connected in series according to the preferred embodiment of the present invention;

Figure 2 shows a plan view of the heating element core connected in parallel, utilizing multi-level power output heating circuit design and optional local area treatments.

Figure 3 shows a plan view of the heating element core, connected in parallel and consisting of various electroconductive threads woven into, laminated between or embroidered on an electrically non-conductive substrate. Optional local area treatments and positive temperature coefficient (PTC) material may be utilized in this embodiment.

Figure 4 shows a plan view of a temperature sensing device designed to limit a number of thermostats in a heating element and to afford a more convenient location for the remaining thermostats.

Figure 5 shows a plan view of a heating element utilizing conductive textile and positive temperature coefficient (PTC) material to create a wide, PTC controlled, heating circuit. This heater offers a combination heating regimes.

Figure 6 shows an isometric view of a tooth connector utilized to attach conductive textile thread, bundle, strand or rope heating cable to a power lead or another heating cable.

Figure 7 shows an isometric view of several embodiments of heating sleeves, utilizing heating elements.

Figure 8 shows a plan view of an infra red glowing embroidered insignia, designed to be visible through the night vision devices.

Figure 9 shows a plan view of a strip heating element installed in window blind vanes to heat the surrounding air.

Figure 10A shows a plan view of the heating element strip laid out in a zigzag pattern, electrically connected in series, and having a thermostat placed on top of fold, according to the preferred embodiment of the present invention;

Figure 10B shows an alternative layout of the heating element strip shown in Figure 11A utilizing gaps between its sections.

Figure 11A shows a cross section of a woven strip with individually insulated conductive threads/fibers or metal wires interwoven with nonconductive threads.

Figure 11B shows a cross section of the heating element core where the individually insulated conductive threads/fibers or metal wires are laminated between two layers of substrate of nonconductive material.

Figure 11C shows a cross section of the multi-conductor heating cable where a non-conductive polymer is extruded around the non-insulated conductive threads/fibers or metal wires. Optional reinforcing threads/fibers are utilized in the design.

Figure 12A shows cross section of a thermostat placed at location of heat concentration in the form of a multiple fold in the length of the heating element strip.

Figure 12B shows a plan view of a thermostat placed at a location of heat concentration in the form of a fold at the change of the heating strip direction.

Figure 13A shows an isometric view of the heating element consisting of a sleeve/pipe woven of the individually insulated conductive threads/fibers or metal wires and non-conductive threads/fibers. Optional reinforcing fibers are utilized in this design.

Figure 13B shows an isometric view of the heating element consisting of a sleeve/pipe formed by extrusion of non-conductive polymer around non-insulated conductive threads/fibers or metal wires. Optional reinforcing threads/fibers are utilized in this design

DETAILED DESCRIPTION OF THE INVENTION

The invention consists of a soft heating element core made by interconnecting of individually insulated conductive metal and/or carbon containing threads/wires with nonconductive yarns/fibers or polymers. Said core is assembled as strips,

sleeves, pipes, sheets and ropes. The heating element core may contain, electrically conducting metal microfibers, metal coated and/or carbon containing threads, which are combined with non-conducting yarns/fibers or polymers in various proportion and/or weaving patterns in order to augment the heating element core electrical resistance. For convenience of explanation of the invention, the term "thread" shall mean stitching thread, knitting thread, and weaving thread or yarn and other structures composed of individual fibers or a combination of fibers where each individual fiber is thin enough to make it as soft, flexible and reliable as a synthetic polymer fiber such as polyester ornylon. For convenience of explanation the term "individually insulated conductive threads/fibers or metal wires" shall mean thin cables made of nonconductive and/or conductive threads/fibers or metal wires, stranded or twisted in a continuous bundle which is then insulated by nonconductive polymer.

The term "metal microfibers" shall mean metal fibers, having denier size of synthetic textile fibers. The diameter of each metal microfiber is smaller than the lowest commercially available metal wire gage.

The term "metal wire" shall mean metal strand having diameter greater than metal fiber or microfiber. Metal wire may contain copper, iron, chromium, nickel, or their combination.

The heating element core described in this invention may comprise one of the following threads/fibers, metal wires or their combination:

1. Metal coated synthetic polymer threads with similar or varying electrical characteristics.

2. Metal coated inorganic threads (made of ceramic or fiberglass fibers) with similar or varying electrical characteristics.

3. Carbon coated inorganic threads (made of ceramic or fiberglass fibers) with similar or varying electrical characteristics.

4. Threads with similar or varying electrical characteristics, impregnated with conductive ink.

5. Metal threads made of metal microfibers with similar or varying electrical characteristics.

6. Metal wires with similar or varying electrical characteristics.

7. Threads/wires, as indicated in 1 through 6 above, with addition of nonconductive polymer synthetic fibers.

8. Threads, as indicated in 1 through 6 above, with addition of nonconductive inorganic, including fiberglass, fibers.

9. Threads/fibers, as indicated in 1 through 8 above with addition of carbon/graphite threads.

The non-conductive material of the heating element core may be in a form of weft or warp weaving yarns, extruded or jacketed insulating polymer, woven or non-woven synthetic fabric or inorganic fibers/textile.

The insulating polymer may be polyvinyl chloride (PVC), silicon rubber, polyethylene, polypropylene, polyurethane, cross-linked polyethylene and PVC, or other cable insulating materials. The laminating of the multiple individually insulated conductive threads/fibers or wires to the non-conductive substrate may be achieved by placing the threads between at least two layers of non-conductive material and subsequent thermal fusing of the sandwich assembly. It is also possible to utilize adhesive or stitching to laminate individually insulated conductive and optional nonconductive threads/fibers between non-conductive material.

The metal coated threads described below in this invention may comprise soft and highly electrically conductive metals such as silver, gold, copper, tin, nickel, zinc, their alloys or multi-layer combination. Such coating may be applied on carbon/graphite, polymer, fiberglass or ceramic threads by sputtering, electroplating, electroless deposition or other appropriate metal coating techniques.

The metal fiber containing threads described in this invention may comprise the following metals or their combination: tungsten, nickel, chromium, and iron. The individual metal fibers within the threads have small enough thickness to make the threads as soft and flexible as those made of polymer textile materials, such as polyester or nylon.

The term "conductive ink" described in this invention shall mean electroconductive ink, paint or adhesive comprising electroconductive media, such as carbon, graphite or metal particles/fibers dispersed in a solution of nonconductive organic stabilizer.

The term "carbon containing threads" described in this invention shall mean carbon/graphite threads or threads coated with carbon or carbon/graphite containing material.

The term "conductive textile" described in this invention shall mean soft electrically conductive substrate comprising electroconductive threads/fibers with or without inclusion of nonconductive materials, such as woven or non-woven textile/fiber.

Fig. 1 shows an example embodiment of electroconductive heating element core (1) in a form of a strip, folded so as to form gaps for subsequent sealing, and patterned as dictated by the heating element design. The conductive strip of the heating element core (1) consists of electroconductive threads (2), disposed

longitudinally in a strip so as to be separated by non-conductive material. Such placement is achieved through weaving, embroidering or laminating of individual threads between at least two layers of insulating material.

Portions of the heating element core (1) may contain localized treatment in order to augment the electrical properties of the finished product, such localized treatment is performed by at least one of the following methods: (a) the use of electroconductive carbon or graphite carrying material (6); (b) the use of positive temperature coefficient (PTC) material (7); (c) the use of highly conductive bridging threads (5) in order to create redundant electrical circuits.

In order to control overheating, at least one temperature control device (12), such as thermostat, is placed within the plane of the heating element. The bends and folds along the length of the heating element core may be secured by at least one of the following shape holding means: (a) sewing with electroconductive threads, preferably metal coated threads, (b) sewing with non-conductive threads; (c) stapling; (d) gluing; (e) riveting; (f) fusing or sealing by breathable or hermetic insulating material (8).

The heating element core is energized through a power cord (3), which is connected to the heating element with metal electrodes (4). The electrodes are flexible and have a flat shape with large contact area. It is also preferable to use conductive textile electrodes comprising copper wires and carbon yarns or electrodes, embroidered to the ends of the heating element core by highly conductive threads. The electrodes may be attached to the ends of the heating element core by sewing, stapling, riveting or using of a toothed connector.

In addition to the electrodes, the power cord has the following attachments: (a) electric plug (11), (b) optional power control device (10), which may include one, some or all of the following: AC to DC converter, transformer, power level regulator, on/off switch.

Depending on the end use of the heating elements, the heating element assembly process utilizes the following operations in any sequence:

(a) folding and shaping the heating element core into a predetermined shape,

(b) attachment or embroidering of the electrodes to the heating element core,

(c) attachment of lead wires, optional thermostat(s) and the power cord to the heating element core,

(d) lamination of the heating element core with the insulating material,

(e) securing the pattern of the heating element assembly by the shape holding means.

It is preferable to utilize a heat reflecting layer on one side of the insulated heating element core if dictated by the heating element design; such heat reflecting layer may be an aluminum foil or a metallized polymer, electrically insulated from the electroconductive heating element components.

Figure 2 shows an example of the heating element core (1) in a form of strips, folded and disposed between the electrical bus electrodes (9), the strips having a straight run and being attached to the parallel bus electrodes by stitching, stapling or riveting. The run of the zigzag, the distance between the peaks, may vary even in the same heating element, thereby varying the finished element temperature density as may be dictated by the heating element design. As a variation of this design, the length of heating element strip (1) between the bus electrodes may be shaped in a zigzag or other pattern instead of being straight. This enables a variation of the

heating element resistance without varying the heating element core material. The heating element can also consist of separate parallel conductive strips electrically connected to the bus conductors. All strips in this embodiment are disposed in such manner as to create gaps between the adjacent strips in order to provide tight hermetic sealing and/or shape holding during insulation by the nonconductive material. The strips are tightly connected with bus conductors (9) by stitching (16), stapling or riveting.

A heating element of this design may contain optional localized treatment in order to augment the electrical properties of the finished product, such localized treatment may be one of the following methods: (a) the use of electroconductive carbon or graphite carrying material, (b) the use of positive temperature coefficient (PTC) material (7), (c) the use of bridging electroconductive threads (5), such as metal coated threads, in order to create redundant electrical circuits.

A novel method of controlling power output is utilized in this embodiment. By using the third bus electrode, shown in the middle, the power output can be varied by a factor of 4, at the same time, requiring 4 times fewer conductive threads. This provides a double benefit of a more versatile heater at a lesser cost. This heater has two working regimes, high power output and low power output.

In the low power output regime, the middle bus electrode is not energized and has no function other than a circuit bridge, providing redundancy in the path of electrical current. In the high power output regime, utilizing direct current, when the middle bus electrode is energized, the outer electrodes are switched to be fed by one power lead, with polarity, opposite to that of the middle bus electrode. When alternating current is utilized, polarity does not matter, however power supply circuit

is identical to that of a direct current circuit-the middle bus electrode is fed by one power lead and the outer electrodes are fed by another.

Energizing the middle bus electrode enables the heater strips to complete the circuits in half the distance, thereby reducing their resistance by one half. This creates two heating circuits, each putting twice the power of the single larger heating circuit. Therefore, the power output from the heating element increases 4 times. Other numerous variations of this design are possible, based on the desired function.

There are examples of prior art where attempts were made to vary temperature and power output within a single heating element, U.S. patent 4,250,397 to Gray at al, U.S. patent 3.739,142 to Johns, and U.S. patent 4,788,417 to Graflind. They all use layering of heating elements to enable power variability. This layering creates considerably heavier, less flexible and more expensive heaters. Additionally, because the temperature between layers is considerably higher than that felt on the outside of the heater, a localized overheating may occur, melting an insulating layer and causing short circuit and fire.

Figure 3 shows an example of heater utilizing various conductive threads (2), such as metal coated synthetic polymer or inorganic threads, carbon coated inorganic threads, threads impregnated with conductive ink, and/or other types of conductive threads woven into, laminated between or embroidered on a non-conductive substrate (14) in any pattern as may be dictated by the heating element design. The non-conductive substrate (14) for embroidering or laminating may be made of woven or non-woven textile, vinyl sheet, silicon rubber, polyethylene or polyurethane sheet or any other synthetic material. This example of heating element contains optional localized treated areas in order to augment the electrical characteristics of the heater.

These localized treated areas may consist of electrical circuit bridging threads (5), positive temperature coefficient (PTC) materials (7), and cut out areas (15). The cut out areas (15) are only one embodiment of gaps, necessary for sealing and/or fusing the outer insulation layer(s). The other embodiments of gaps may be areas of non-conductive material between conductive threads.

The optional PTC material may be located in the middle of the heating element between the bus electrode conductors (9), as shown in Fig.3, near at least one bus electrode conductor or combined with at least one of the bus electrode conductors as its integral component.

The heater is energized by power cord (3), equipped with electric power level controller (10) and a plug (11). It is important to note that embroidering of a heating element circuit provides for virtually unlimited flexibility of design and is a novel and unique approach in making of heating elements. Embroidering on or laminating of the conductive threads between the nonconductive materials reduces the weight and cost of the heating element.

Figure 4 shows a novel temperature sensing device (13), which senses a localized temperature change and, being highly thermoconductive, delivers heat to a thermostat (12) from different heating areas. This enables placement of thermostats in the least objectionable locations. For example, in the case of a heating pad, mattress pad or a heating blanket, thermostats may be located at the power cord attachment location and/or at the edges of an appliance. Utilizing this device may also reduce the number of necessary thermostats. The device consists of a highly thermoconductive strip or threads disposed across the heating element core and preferably insulated from one side to prevent the dissipation of heat. One end of the

thermoconductive strip or bundle of threads is attached to or wound around a thermostat so as to enable its quick activation in case of overheating of the heating element assembly. The thermoconductive sensor may also be in a form of a patch placed on top or under a thermostat and having an area considerably larger than the thermostat.

Figure 5 shows a heating element, which utilizes known positive coefficient (PTC) technology with conductive textile technology, creating a novel and synergetic effect. It enables creation of a wide, PTC controlled, heating circuit through energizing busses (A) and (C), and narrow, PTC controlled, heating circuit through energizing busses (A) and (B), all in one heater. This embodiment also allows for a heating surface with temperature limits above those of PTC, when energized through busses (B) and (C). Numerous combinations or sequence of bus electrodes (9), PTC material (7) and conductive textile (1) are possible, depending on the end use requirements.

Figure 6 shows an example of embodiment of heating element core (1) in a form of a thread, bundle of threads, or a rope. The heating element core, covered by insulating layer (8), is energized through a power cord, which is connected to the heating element with pressure connector (4). The tight connection to the heating cable is achieved through insertion of the tooth connector (17) into a transverse cut in the heating cable and subsequent tight squeezing of the pressure connector shell around the tooth (17).

This heating element core may also be utilized in a flat heater by laying it out in a pattern dictated by the heating element design on a shape holding and/or

insulating substrate so as to form gaps for subsequent sealing by the shape holding/insulating material.

Figure 7 shows example of tubular heating elements intended for heating of pipes or as heating sleeves for various heating purposes, including health and industrial applications. Figure 7(A) shows a heating sleeve with bus electrodes (4) located at the ends and the resistance threads (2) connected to the busses in parallel. Optional circuit bridging threads (5) may be utilized to provide electrical continuity and continued heating capability in case of localized damage to a limited number of heating threads (2). This type of heating element may be utilized when the length and the power output of a heater are known fixed quantities.

For the variable length heating elements an embodiment shown in Fig 7(B) is more suitable. This embodiment shows a heating element with bus electrodes (9) placed longitudinally, extending full length of the heating element. The resistance threads (2) are connected to the busses in parallel. Optional circuit bridging threads (5) may be utilized to provide electrical continuity in case of localized damage to a limited number of heating threads (2). Figure 7 (C) shows a variation of the heating element shown in Fig 7(B) utilizing optional PTC material in order to control localized overheating and forgo the use of thermostat.

Figure 8 shows an embodiment of a heating element utilizing electroconductive threads (2) to embroider a desired pattern or design on an electrically non-conductive substrate (8).

One of the uses for this design is in military and/or law enforcement, where an identifying insignia can be embroidered on the personnel closing to enable easy identification in the darkness while using night vision scopes. Only a small power

source (18), sufficient to generate up to 0.1 Wt/inch^2, will provide adequate heat to be clearly distinguishable through the night vision devices.

Figure 9 shows an embodiment of a heated window blinds vane. It utilizes conductive textile strips (1) held in a desired shape and insulated by fusible interfacing (8). The finished heating element is then installed into a fabric or plastic window blinds vane. The conductive strip is connected through power leads (3), to a power source located in the window blinds track. A similar design may be utilized in ceiling fan blades in order to heat circulated air or to provide localized comfort heating in modular office partitions/dividers.

Fig. 10A shows a possible embodiment of the invention where a heating element consists of heating element core (101), having a shape of a strip, which is laid out in a zigzag pattern. The sections of the strip are contiguous to each other. The heating element core consists of multitude thin cables made of individually insulated conductive threads/fibers or metal wires (102), disposed longitudinally in a strip so as to be separated by non-conductive material. Such placement is achieved through weaving of conductive cables with nonconductive threads or laminating of individually insulated conductive threads/fibers or metal wires between at least two layers of insulating material. The ends of heating element core are stripped of insulation and attached to the terminals (104) and lead wires (103). The terminals (104) may vary from flat electrodes to special crimping splices. The individually insulated threads/fibers or metal wires are electrically connected in parallel in the heating element strip in the shown embodiment of the invention.

In addition to the terminals/electrodes (104), the power cord (110) has the following attachments: (a) electric plug (108), (b) optional power control device

(106), which may include one, some or all of the following: AC to DC converter, transformer, power level regulator, on/off switch. An automatic temperature limit control is accomplished through the use of an optional thermostat (105) placed directly on the surface of the heating element core (101), preferably at the location of a heat concentration, such as fold (109). As an alternative to a thermostat or, if dictated by a particular design, in addition to it, optional heating sensor (107) may be utilized.

The heating sensors (107) may be in a form of threads/fibers or metal wires incorporated into the heating element core (101) specifically for this purpose or the individually insulated threads/fibers or metal wires (102) can themselves be utilized as sensors. Thus the sensing means may be electrically connected to a separate electrical circuit, specifically designated for temperature control or it may be connected in parallel with other individually insulated threads/fibers or metal wires.

It is important to note that the heating threads/fibers (102), when made from metal coated or carbon containing material coated polymer threads/fibers, can function as TCO safety devices. One, several or all heating threads/fibers may serve this function, depending on the intended use of heater and its design parameters. It is desirable that the limiting (melting) temperature for such TCO threads/fibers be in a range of 120°C-300°C. This virtually eliminates the possibility for the heating element to become a source of ignition in case of localized overheating, short circuit or other extreme conditions. It is also important to note that melting temperature can be the same or vary for different heating threads/fibers within one heating element core.

Another distinguishing characteristic of metal coated or carbon containing material coated polymer threads/fibers described in this invention is that as the temperature approaches their melting limit, their electrical resistance rises, thus lowering their power output of the heating element. This temperature self-limiting (TSL) capability is also a very important safety feature.

It is also preferable to utilize combination of threads with different thermal characteristics in one heating element core. For example, one heating element strip may contain 3 insulated cables of electroconductive threads/fibers, two of which are made of metal coated synthetic threads having TCO function, and the third cable made of carbon or metal fibers. The threads of the third cable do not have TCO function and can withstand temperatures, exceeding TCO melting limit of other two cables. In the event all 3 cables have the same electrical resistance, each of them will provide 1/3 of electrical power and heat radiated by the heating element. When the temperature of the heating element reaches TCO limit, two cables will melt and open the circuit, reducing the total generating power/current by 2/3. Thus, the heat generated by the system will be significantly reduced, minimizing overheating and fire hazards. It is also possible to utilize threads/fibers with different thermal characteristics in the same individually insulated cables. For example, one cable may contain metal coated synthetic fibers, having TCO capabilities, and metal or carbon fibers which have very high temperatures of decomposition.

Figure 10B shows an alternative layout of the heating element core (101) utilizing gaps between its sections.

The ability to provide a very wide flexibility of the heating element design and the possibility of providing numerous safety features, such as thermostat placed on the

heating element surface at a point of heat concentration, thermal sensor threads/fibers or wires, TCO threads/fibers, and TSL feature makes this invention novel and its technology superior to those of prior art.

Some of the features, such as TCO and TSL are available only in highly specialized, limited and expensive prior art heating elements, and are based on expensive fabrication technologies, which are different to those described in present invention. It is preferable to utilize a heat reflecting layer on one side of the insulated heating element core if dictated by the heating element design; such heat reflecting layer may be an aluminum foil or a metallized polymer, electrically insulated from the electroconductive heating element components.

Figures 11A, 11B and 11C show alternative examples of the construction of the heating element core.

Figure 11A shows a cross section of a woven strip where individually insulated conductive threads/fibers or metal wires (102) are interwoven with nonconductive threads. It is important to use non-conductive threads having low thermal shrinkage, such as fiberglass, in order to prevent deformation of the heating element core during heating operation. This design allows for a wide range of the heating element core width, from narrow strips to wide sheets.

Figure 11B shows a cross section of a heating element core, where individually insulated conductive threads/fibers or metal wires (102) are laminated between two strips or sheets of woven or non-woven fabric (112). This design also allows for a wide range of cost effective heating elements, from narrow strips to wide sheets. Optional reinforcing fibers/threads (113) can be added when required by the design. It is also possible to laminate thin conductive cables (102) onto only one

strip/sheet of substrate material (112) consisting of woven or non-woven fabric, polymer, foil or other suitable substrate.

Figure 11C shows a cross section of an extruded multi-conductor cable consisting of non-conductive polymer extruded around electroconductive threads/fibers or metal wires (114). Optional reinforcing fibers/threads (115) can be added to provide required strength of the heating element.

Figure 12A and 12B show details of placement of thermostat (105) at location of heat concentration. Heat concentration occurs at folds and where heating threads/fibers or wires are placed closer together in one section of a heating element than in other sections. Figure 3B shows placement of thermostat on the top of the fold produced by a change in the direction of the heating element strip. It is also possible to wrap thermostat by the conductive strip instead of placing it on the top of folded surface of said strip. Such preferable placements of thermostat increase its response to heat elevation, which allows control on/off cycling of the heating system.

Upon placement of thermostat at the location of heat concentration it is preferable to thermally insulate the location of this assembly in order to avoid dissipation of heat from the thermostat. Alternatively to a thermostat, another form of temperature sensing device, such as thermocouple, connected to the temperature controller, may be utilized.

Undesirable and uncontrolled multiple folding of the heating element can occur in various soft and flexible heating units such as heating blankets and mattress pads. Placement of thermostat, having pre-set temperature limit, on multi-folded portion of the heating element, simulates similar conditions to those having abnormal elevated temperature in any part of the unit not controlled by temperature sensing

device. Such construction significantly reduces the amount of thermostats and assembly cost in foldable heating devices having large heat radiating surface area. It is also desirable to utilize other temperature sensing devices, instead of thermostats, such as thermocouples, to provide controlled cycling of the heating element operation in the described embodiments of this invention.

Figure 13A shows isometric view of a woven sleeve/pipe heating element core where the individually insulated conductive threads/fibers or metal wires (102) are interwoven with nonconductive threads (111). Optional reinforcement threads (113) are added when required by the design.

Figure 13B shows an isometric view of an extruded multi-conductor sleeve/pipe heater consisting of non-conductive polymer insulation (115) extruded around the non-insulated heating thread/fibers or metal wires (114). Optional reinforcement fibers/threads (113) are added when required by the design.

In addition to the preferred embodiments shown in Figures 13A and 13B a possible embodiment of a sleeve/pipe heater may have a construction consisting of the individually insulated conductive threads/fibers or metal wires, that are laminated between two layers of woven or non-woven fabric or polymer. Optional reinforcing threads/fibers can be added when required by the design.

It is important to note that individually insulated conductive threads/fibers or metal wires can also be laminated onto only one layer of substrate material consisting of woven or non-woven fabric, polymer, foil or other suitable substrate. The proposed soft heating elements may be utilized in a variety of commercial and industrial heater applications, utilizing direct or alternating current. The main

advantage of these heating elements is the high reliability, which is provided by the tightly sealed soft and durable electrically conductive threads.

The proposed soft heating elements may be utilized in a variety of commercial and industrial heater applications, utilizing direct or alternating current. The main advantage of the heating elements is the high reliability, which is provided by the tightly sealed soft and durable electrically conductive threads.

The process of manufacturing of the insulated heating elements can be fully automated, it utilizes commercially available non- toxic, nonvolatile and inexpensive products. Some designs of the insulated heating core may be manufactured in rolls or spools with subsequent cutting to desired sizes and further attachment of electric power cords and optional power control devices.

The softness and the low temperature density of the conductive heating elements of the invention enable its utilization in novel and unique applications. One of such applications is a heat/cool pad for therapeutic use. This pad combines a surface heating element, a heat/cold conserving gel, and a refrigeration circuit placed inside or close to the gel pouch. This design enables an alternating heat and cold application with the same device. The variation of such gel pouch design may include a heat function only. The uses of such gel containing devices are very versatile and may include child car seat/carrier heater, food warmer/cooler, comfort heating and cooling pads, and other devices.

Further, the use of electrically conductive metal coated threads, carbon coated inorganic threads, threads impregnated with conductive ink, carbon/graphite yarns, non-conductive ceramic or polymer fibers in the heating element has the following additional advantages:

it enables manufacturing of thin, soft and uniformly heating devices without utilizing conventional metal heater wires;

it provides high durability of the heating appliances which can withstand sharp folding, small perforations, punctures and compression without decreasing of electrical operational capabilities;

it provides high tear and wear resistance owing to: (a) high strength of the conductive threads and (b) tight enveloping around all electrically conductive media with strong insulating materials;

it provides for manufacturing of corrosion and erosion resistant heating element owing to: (a) high chemical inertness of the carbon coated inorganic threads and ceramic yarns, (b) hermetic polymer insulation of the whole heating element, including electrode connections and temperature control devices, for utilization in chemically aggressive industrial or marine environments;

it offers versatility of variation of the electrical conductivity of the heating element core owing to: (a) weaving, embroidering or stranding of the electrically conductive threads to the predetermined width and thickness of the strips, sleeves, sheets, ropes or strands of threads; (b) weaving of the yarns to the predetermined density or type of weaving; (c) weaving, embroidering or stranding of the conductive threads having different electrical conductivity in one unit; (d) weaving, embroidering or stranding of the conductive threads with nonconductive ceramic and/or polymer threads or fibers. (e) making cut outs of different shapes to vary the electrical resistance of the heating element core.

it provides for saving of electric power consumption owing to: (a) installation of heat reflective layer and (b) possibility of placing the heating element with less cushioning and insulation closer to the human body or to the heated object;

it allows for manufacturing of heating element with electrical connection of electrically conductive strips, ropes, sheets, sleeves/pipes or strands in parallel or in series;

it overcomes the problem of overheated spots owing to (a) high heat radiating surface area of the heating element core, (b) uniform heat distribution by the heat reflective layer, reducing the possibility of skin burns or destruction of the insulating layers;

it provides for extremely low thermal expansion of the heating element owing to the nature of the electrically conductive threads, polymer or nonconductive yarns/fibers. This feature is extremely important for construction applications (Example: concrete) or for multi-layer insulation with different thermal expansion properties;

it offers high degree of flexibility and/or softness of the heating appliances depending on the type and thickness of insulation; and

it provides technological simplicity of manufacturing and assembling of said heating element.

Further, a combination of the electrically conductive threads and PTC material allows to: (a) provide temperature self-limiting properties to the soft heating appliances, eliminating need for thermostats; (b) increase the distance between the bus electrodes, decreasing the risk of short circuit between said bus electrodes; (c) provide larger heat radiating area resulting in higher efficiency of the heater; (d) provide a

barrier for liquid penetration to the parallel bus conductors in the event of puncturing the insulated heating element core.

Further, the proposed heating elements can be utilized in, but not limited to: (a) electrically heated blankets, pads, mattresses, spread sheets and carpets; (b) wall, office dividers, window blind vanes, fan blades, furniture, ceiling and floor electric heaters; (c) vehicle, scooter, motorcycle, boat and aircraft seat heaters; (d) electrically heated safety vests, garments, boots, gloves, hats and scuba diving suits; (e) food (Example: pizza) delivery and sleeping bags; (f) refrigerator, road, roof and aircraft/helicopter wing/blade deicing systems, (g) pipe line, drum and tank electrical heaters, (h) electrical furnace igniters, etc. In addition to the heating application, the same conductive textile heating element core may be utilized for an anti static protection.

The aforementioned description comprises different embodiments which should not be construed as limiting the scope of the invention but, as merely providing illustrations of some of the presently preferred embodiments of the invention. Additional contemplated embodiments include: (a) heating element core may include yarns made of ceramic fibers, such as alumina, silica, boria, boron nitride, zirconia, chromia, magnesium, calcia, silicon carbide or combination thereof; (b) heating element core may comprise electrically conductive carbon/graphite or metal coated ceramic fibers, such as alumina, silica, boria, zirconia, chromia, magnesium, calcia, silicon carbide or combination thereof; (c) the metal coating can be applied on carbon/graphite threads/yarns; (d) the strips can be soaked in a diluted solution of adhesives and dried, to ease the hole cutting during manufacturing of the heating element core and augmentation of its electrical properties; (e) the heating

element assembly may comprise the conductive strips, ropes, sleeves/pipes, sheets or threads, having different electrical resistance; (f) the heating element core may be formed into various patterns such as serpentine or other desired patterns, including ordinary straight, coil or "U" shaped forms; (g) the electric power cord can be directly attached to the conductive heating element core without the use of electrodes, it is possible to utilize electrically conductive adhesive, conductive paint, conductive polymer, etc. to assure good electrical connection; (h) the conductive heating element core can be electrically insulated by the soft non- conductive fabrics or polymers by sewing, gluing, fusing, spraying, etc., forming a soft multi-layer assembly; (i) the conductive soft heating element core can be electrically insulated by rigid non-conductive materials like ceramics, concrete, thick plastic, wood, etc.; (j) the shape holding means can be applied on any part of the heating element core; (k) the heating element core may be first insulated by the non-conductive material and then laid out in a desired pattern.

While the foregoing invention has been shown and described with reference to a number of preferred embodiments, it will be understood by those possessing skill in the art that various changes and modifications may be made without departing from the spirit and scope of the invention.

CLAIMS

1. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

at least one continuous electrically conductive textile strip of desired length, which comprises metal containing textile threads as electrical resistance heating means, said strip is laid out in predetermined pattern to fit an area of said heater;

at least one gap between portions of at least one of said heating strips;

a conductive electrode means for introducing an electrical current to said heating means;

an insulating means for insulating at least said metal containing textile threads with nonconductive means.

2. The soft heater according to claim 1, wherein said metal containing textile threads comprise metal coated synthetic polymer textile threads.

3. The soft heater according to claim 1, wherein said metal containing textile threads comprise metal coated inorganic textile threads.

4. The soft heater according to claim 1, wherein said metal containing textile threads comprise electrically conductive metal coated carbon, textile threads.

5. The soft heater according to claim 1, wherein said metal containing textile threads comprise metal fiber containing textile threads.

6. The soft heater according to claim 1, further including conditioned local spots for providing redundant electrical circuits and control of electrical resistance in said heating strips.

7. The soft heater according to claim 1, further including conditioned local spots in the selected areas of the heater, said local spots comprise a positive temperature coefficient material for providing temperature self limiting capabilities to said heater.

8. The soft heater according to claim 6, wherein said conditioned local spots are the selected areas, comprising electrically conductive carbon carrying material.

9. The soft heater according to claim 6, wherein said redundant electrical circuits comprise electrically conductive textile threads bridging electrical circuits between the threads of said electrical resistance heating means.

10. The soft heater according to claim 1 further including a shape holding means for connecting and holding said portions of the heating strip in the predetermined pattern.

11. The soft heater according to claim 1, further including a heat reflecting layer, placed on at least one side of said soft heater, and electrically insulated from said electrically conductive textile heating strip and said conductive electrode means.

12. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

a plurality of continuous electrically conductive textile heating strips of desired length, which comprise metal containing textile threads as electrical resistance heating means, said heating strips are laid out in predetermined pattern to fit an area of said heater; at least one gap between portions of at least one of said heating strips;

a conductive electrode means for introducing an electrical current to said heating means;

an insulating means for insulating at least said metal containing textile threads with nonconductive means.

13. The soft heater according to claim 12, further including conditioned local spots for providing redundant electrical circuits and control of electrical resistance in selected areas of said heating strips.

14. The soft heater according to claim 12, further including conditioned local spots in selected areas of said heating strips, said local spots comprise a positive temperature coefficient material for providing temperature self limiting capabilities to said heating means.

15. The soft heaters according to claim 12, wherein said metal containing textile threads comprise metal coated synthetic polymer textile threads.

16. The soft heater according to claim 12, wherein said metal containing textile threads comprise metal coated inorganic nonmetallic textile threads.

17. The soft heater according to claim 12, wherein said metal containing textile threads comprise metal coated carbon textile threads.

18. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

a conductive electrode means for introducing an electrical current to said heater;

a soft electrical resistance heating means comprising metal coated nonmetallic textile threads, electrically connected to said conductive electrode means;

an insulating means for insulating at least said metal coated nonmetallic textile threads with nonconductive means.

19. The soft heater according to claim 18, further including conditioned local spots for providing redundant circuits and control of electrical resistance in selected areas of said heating means.

20. The soft heater according to claim 18, further including conditioned local spots in selected areas of said heating means, said local spots comprise a positive temperature coefficient material for providing temperature self limiting capabilities to said heater.

21. The soft heater according to claim 18 further including:

at least two conductive electrode means for introducing electrical current to said heater, said electrode means are disposed at the edges of said heating means, at least one selected area of said heater comprising positive temperature coefficient material, at least one portion of electroconductive textile, disposed longitudinally between at least two of said conductive electrode means, providing that each one portion of said positive temperature coefficient material directly connects to not more than one of said conductive electrode means.

22. The soft heater according to claim 21, wherein said positive temperature coefficient material connects to said conductive electrode means by embedding said electrode means in said positive temperature coefficient material.

23. The soft heater according to claim 18, wherein said conductive electrode means are thin metal coated textile threads incorporated into a matrix of said heating means.

24. The soft heater according to claim 18, further including a heat reflecting layer, placed on at least one side of said heater, and electrically insulated from said heating means and said conductive electrode means.

25. A soft textile heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

a conductive electrode means for introducing an electrical current to said heater;

a soft electrical resistance heating means, comprising individual textile threads impregnated with electrically conductive ink, said textile threads are electrically connected to said conductive electrode means;

an insulating means for insulating at least said textile threads with nonconductive means.

26. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

a conductive electrode means for introducing an electrical current to said heater;

a soft heating element core, comprising carbon coated nonmetallic inorganic textile threads as electrical resistance heating means, said textile threads are electrically connected to said conductive means;

an insulating means for insulating at least said carbon coated nonmetallic inorganic threads with nonconductive means.

27. The soft heater according to claim 26, further including conditioned local spots for providing redundant circuits and control of electrical resistance in selected areas of said heating element core.

28. The soft heater according to claim 26, further including conditioned local spots in selected areas of said heating element core, said local spots comprise a positive temperature coefficient material for providing temperature self limiting capabilities to said heater.

29. The soft heater according to claim 26, further including:

at least two bus conductors, running through a length of said heater,

at least one selected area of said heater comprising positive temperature coefficient material,

at least one portion of electroconductive textile, disposed longitudinally between at least two of said bus conductors, providing that each one portion of said positive temperature coefficient material directly connects to not more than one of said bus conductors.

30. The soft heater according to claim 28, wherein said positive temperature coefficient material connects to said bus conductors by embedding said bus conductor in said positive temperature coefficient material.

31. The soft heater according to claim 26, wherein said conductive means are thin metal coated threads incorporated into the matrix of said heating element core to form bus electrode assembly.

32. The soft heater according to claim 26, further including a heat reflecting layer, placed on at least one side of said heater, and electrically insulated from said heating element and said conductive means.

33. A soft textile heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

electrically conductive textile sleeve of continuous cross-section, comprising carbon containing textile threads as electrical resistance heating means;

a conductive electrode means for introducing an electrical current to said heating means;

an insulating means for insulating at least said carbon containing textile threads with nonconductive means.

34. The soft heater according to claim 33, wherein said carbon containing textile threads comprise threads impregnated with electrically conductive ink.

35. The soft heater according to claim 33, further including conditioned local spots for providing redundant electrical circuits and control of electrical resistance in selected areas of said heating means.

36. The soft heater according to claim 33, wherein said conditioned local spots comprise a positive temperature coefficient material for providing temperature self limiting capabilities to said soft heater.

37. The soft heater according to claim 33 including:

at least two conductive electrode means for introducing current to said heating means, said electrode means run through the whole length of said heater, at least one conditioned local spot in said soft heater comprising positive temperature coefficient material, at least one portion of said electroconductive textile sleeve, disposed longitudinally between at least two of said electrode means, providing that each one portion of said positive temperature coefficient material directly connects to not more than one of said electrode means.

38. The soft heater according to claim 37 wherein said positive temperature coefficient material connects to said conductive electrode means by embedding said electrode means in said positive temperature coefficient material.

39. The soft heater according to claim 18 wherein said soft heating means is a heating cable encapsulated by at least one layer of insulating means.

40. The soft heating cable according to claim 39, wherein said heating means is a rope.

41. The soft heating cable according to claim 39, wherein said heating means is a strand of threads.

42. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising electrically conductive textile threads as electrical resistance heating means, said textile threads are electrically connected in parallel and disposed between two exterior and at least one interior conductive electrode means for introducing current to said heating means, said electrode means are electrically interconnected in such manner as to enable electrical operating regimes comprising: energizing of said heater through exterior electrode means from power leads with differing electrical potential, energizing of said heater in such manner that the adjacent energized electrode means, including interior electrode means, have different electrical potential.

43. A soft textile heater having a durable construction for incorporation into a plurality of articles, said heater comprising:

electrically conductive textile sleeve of continuous cross-section, comprising conductive carbon coated inorganic textile threads as electrical resistance heating means;

a conductive electrode means for introducing an electrical current to said heating means;

an insulating means for insulating at least said conductive carbon containing threads with nonconductive means.

44. A means of controlling localized overheating in a soft heater comprising electrically conductive textile strip as electrical resistance heating means and comprising at least one thermostat disposed on said heating textile strip, at least one flexible thermal

conductor attached to said thermostat and disposed over a portion of said heater beyond that covered by the body of said thermostat.

45. A soft heater having a durable construction for incorporation into a plurality of articles, said heater comprising electrically conductive textile threads, as electrical resistance heating means, embroidered in a desired pattern on a flexible nonconductive substrate; and

a conductive electrode means for introducing an electrical current to said heating means.

46. The soft heater according to claim 45, wherein said conductive textile threads comprise carbon containing nonmetallic textile threads.

47. The soft heater according to claim 45, wherein said conductive textile threads comprise metal coated nonmetallic textile threads.

48. The soft heater according to claim 45, wherein said conductive textile threads comprise metal fiber containing textile threads.

49. A flexible heater having a durable construction for incorporation into a plurality of articles, said heater comprising at least one section of electrically conductive textile, as electrical resistance heating means, disposed longitudinally between at least two parallel conductive electrode means for introducing current to said heating means,

provided that at least one of said two electrode means is electrically connected to a positive temperature coefficient material directly connected to at least two parallel electrode means.

50. The soft heater according to claim 1, further including a heat conserving gel, hermetically sealed into a pouch by the nonconductive means and disposed on at least one side of said insulated heating means.

51. The soft heater according to claim 50, further including a refrigeration circuit to provide for alternating heating and cooling cycles.

52. The soft and flexible heating element according to claim 1, further including electrical resistance sensor disposed through the whole length of said strip for providing overheating control capabilities to said heater.

53. A soft and flexible heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

at least one soft and flexible continuous electrically conductive textile strip, comprising metal wires as electrical resistance heating means, said strip is cut to a desired length and laid out in predetermined pattern to fit the heated area, providing that said soft heating element comprises at least one gap between portions of at least one of said strips;

a conductive electrode means for introducing an electrical current to said strip;

an insulating means for insulating at least said heating means with nonconductive means.

54. A soft and flexible heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

at least one soft and flexible continuous textile strip, comprising, electrically conductive textile threads as electrical resistance heating means , said strip is cut to a desired length and laid out in predetermined pattern to fit the heated area, providing that said soft heating element comprises at least one gap between portions of at least one of said strips;

at least one thermostat, attached to the surface of said strip in the area of enhanced heating;

a conductive electrode means for introducing an electrical current to said strip;

an insulating means for insulating at least said electrically conductive threads with nonconductive means.

55. The soft and flexible heating element according to claim 54, wherein said area of enhanced heating comprises folded portions of said strip.

56. A soft and flexible heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

a conductive electrode means for introducing an electrical current to said heating element;

a soft heating element core, comprising carbon coated nonmetallic inorganic textile threads as electrical resistance heating means, said threads are electrically connected to said conductive electrode means;

at least one thermostat, attached to the surface of said heating element core in the area of enhanced heating;

an insulating means for insulating at least said carbon coated nonmetallic inorganic textile threads with nonconductive means.

57. A soft heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

a conductive electrode means for introducing an electrical current to said heating element;

an electrical resistance heating means, comprising textile threads impregnated with conductive ink, said threads are electrically connected to said conductive electrode means;

an insulating means for insulating at least said textile threads with nonconductive means.

58. A soft and flexible heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

electrically conductive sleeve of continuos cross-section, comprising metal containing textile threads as electrical resistance heating means;

a conductive electrode means for introducing an electrical current to said conductive sleeve;

an insulating means for insulating at least said metal containing textile threads with nonconductive means.

59. The soft and flexible heating element according to claim 58, wherein said metal containing textile threads comprise metal coated textile threads.

60. The soft and flexible heating element according to claim 58, wherein said metal containing textile threads comprise metal fibers.

61. The soft and flexible heating element according to claim 58, further including at least one temperature sensing means disposed longitudinally in said sleeve.

62. A soft and flexible multiconductor heating cable having a durable construction for incorporation into a plurality of articles, said heating cable comprising: electroconductive metal coated nonmetallic fibers, incorporated into continuous textile threads as electrical resistance heating means, said threads are encapsulated by insulating means and separated from each other by said insulating means, said cable cut into desired length and electrically terminated by electrode connectors.

63. A soft and flexible multiconductor heating cable having a durable construction for incorporation into a plurality of articles, said heating cable comprising:

electroconductive metal fibers, incorporated into continuous textile threads as electrical resistance heating means, said threads are encapsulated by insulating means and separated from each other by said insulating means, said cable cut into desired length and electrically terminated by electrode connectors.

64. A soft and flexible multiconductor heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

at least one continuous strip, comprising multiple, individually insulated, electrically conductive cables as electrical resistance heating means, said cables are disposed longitudinally in said strip, separated from each other by nonconductive means and connected with said nonconductive means;

an area of heat concentration comprising at least one fold along the length of said strip;

at least one temperature sensing device attached to the surface of said strip in the area of said heat concentration;

a conductive electrode means for introducing an electrical current to said strip.

65. The soft multiconductor heating element according to claim 64, wherein said temperature sensing device comprises thermostat.

66. The soft multiconductor heating element according to claim 64, wherein said multiple, individually insulated, electrically conductive cables are electrically connected in parallel.

67. A soft and flexible multiconductor heating element having a durable construction for incorporation into a plurality of articles, said heating element comprising:

at least one continuous strip, comprising multiple, individually insulated, electrically conductive cables as electrical resistance heating means, said cables are disposed longitudinally in said strip, separated from each other by nonconductive means and connected with said nonconductive means;

at least one temperature sensing means disposed longitudinally through the whole length of said strip;

a conductive electrode means for introducing an electrical current to said strip.

68. The soft multiconductor heating element according to claim 67, wherein said temperature sensing means and said electrically conductive cables are electrically connected in parallel.

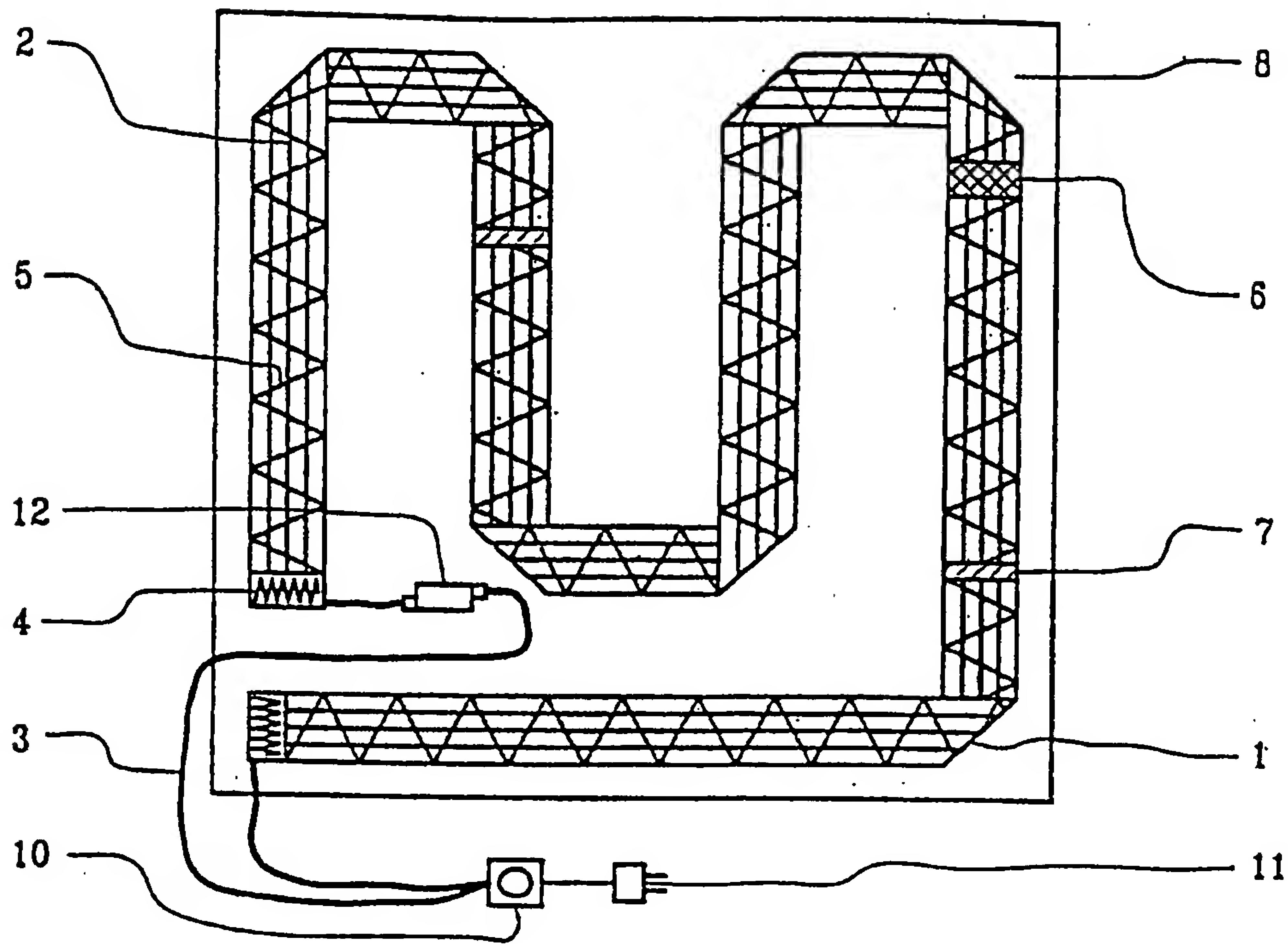

FIG. 1

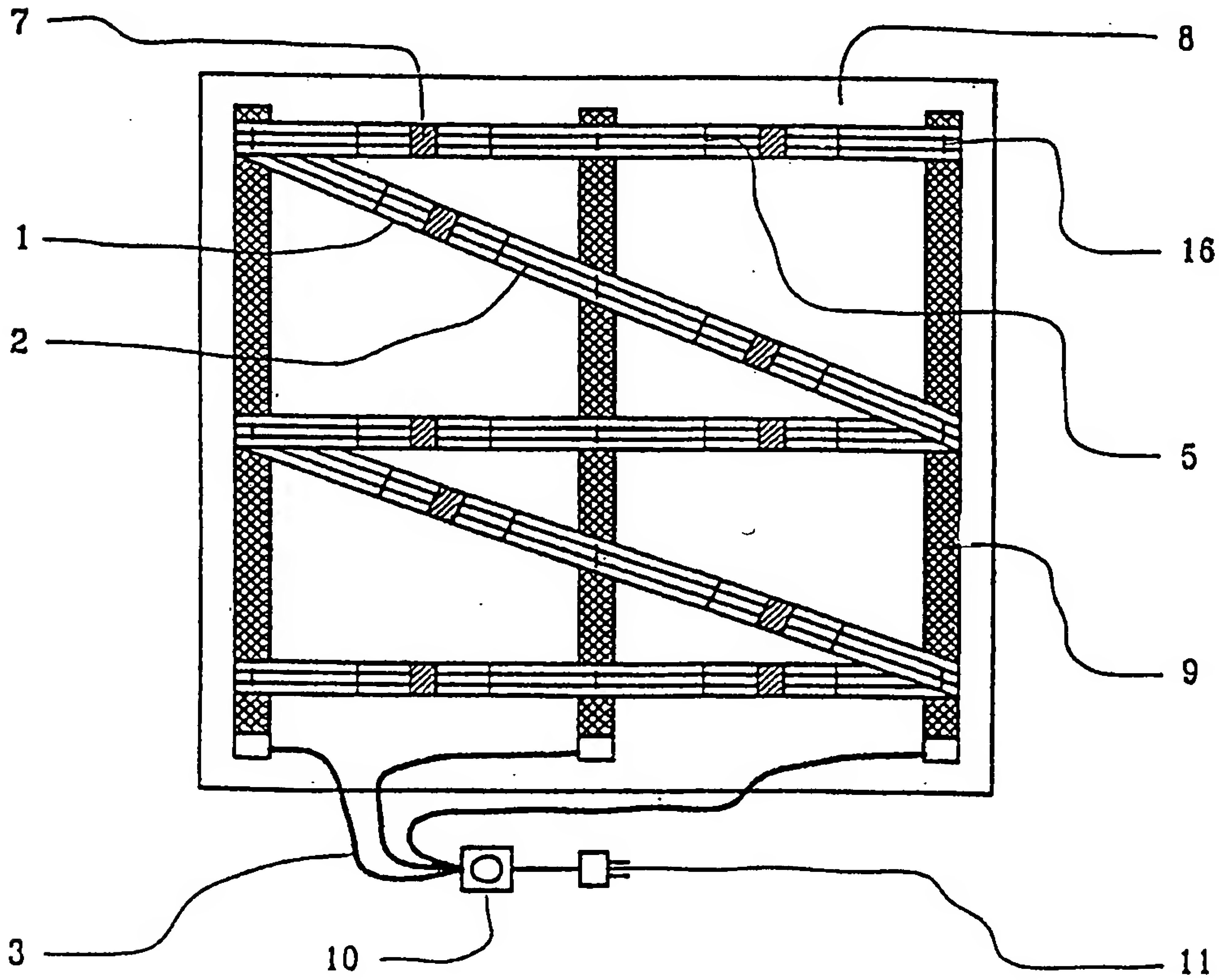

FIG. 2

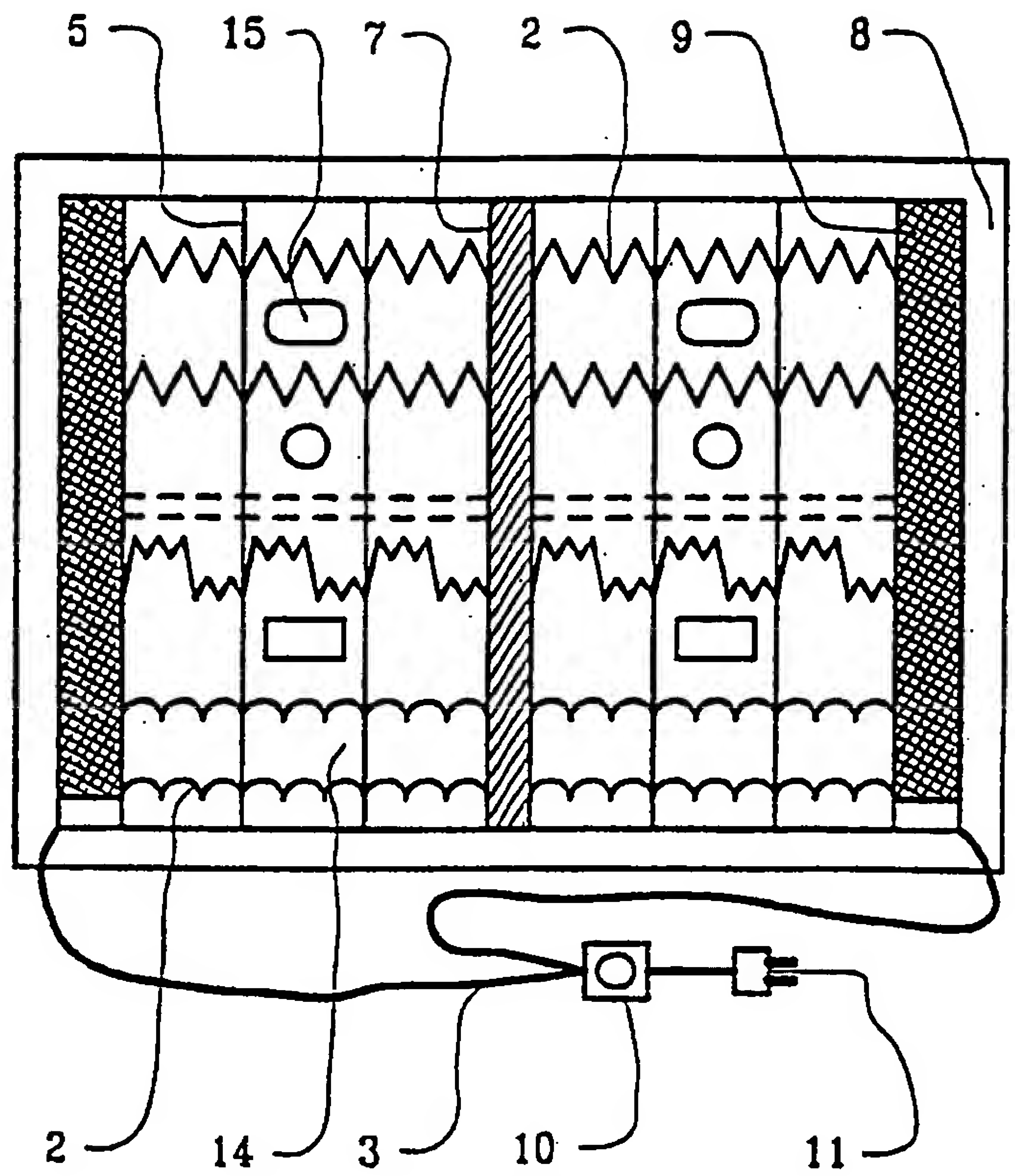

FIG. 3

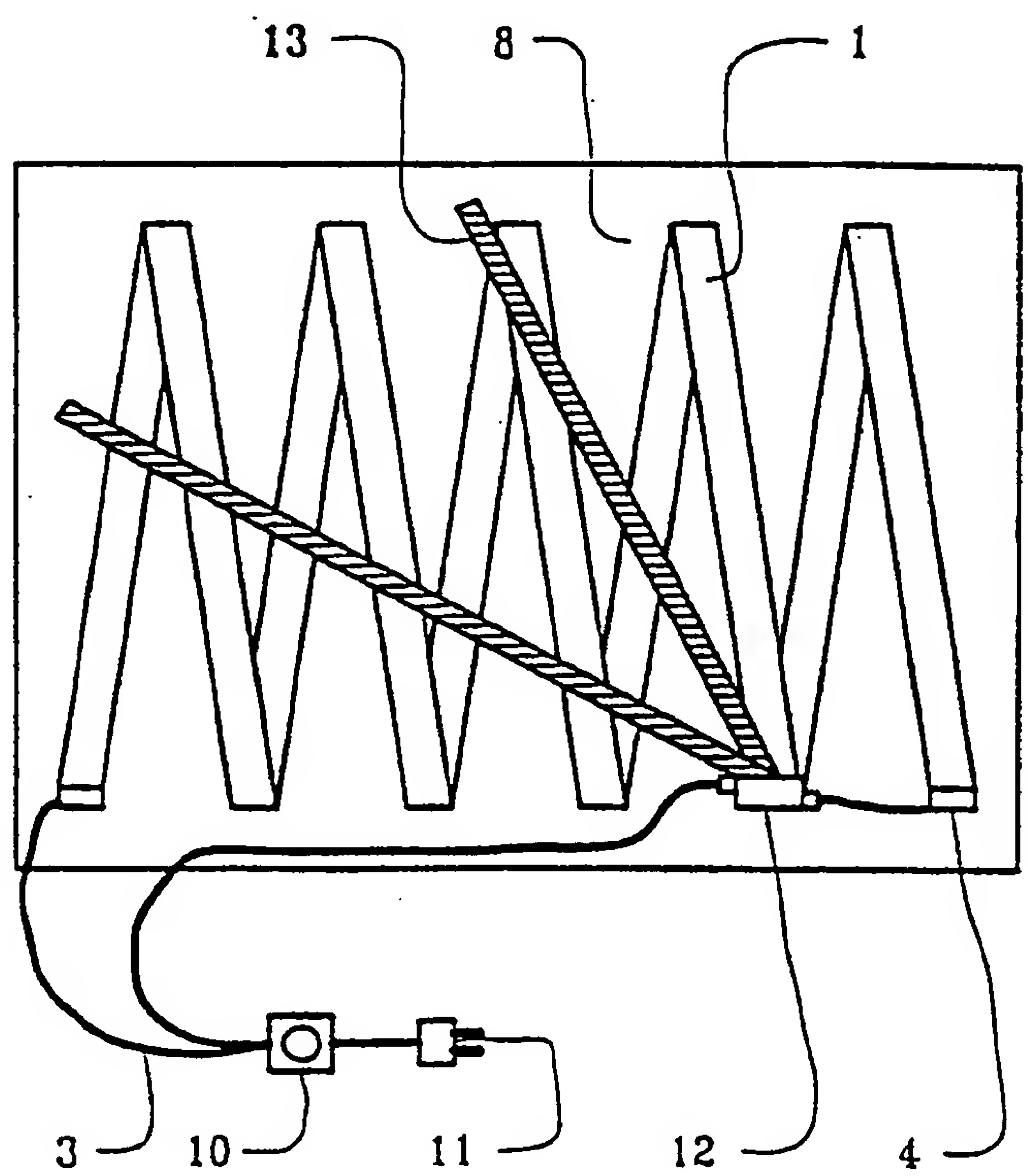

FIG. 4

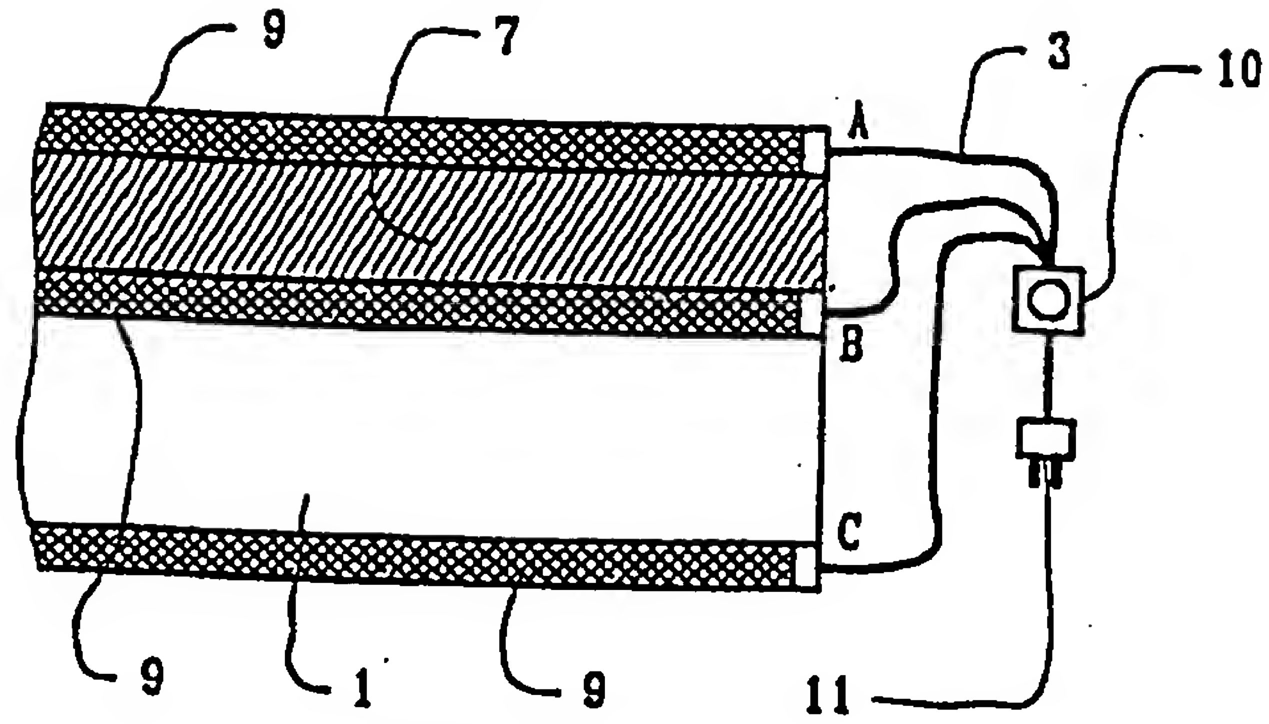

FIG. 5

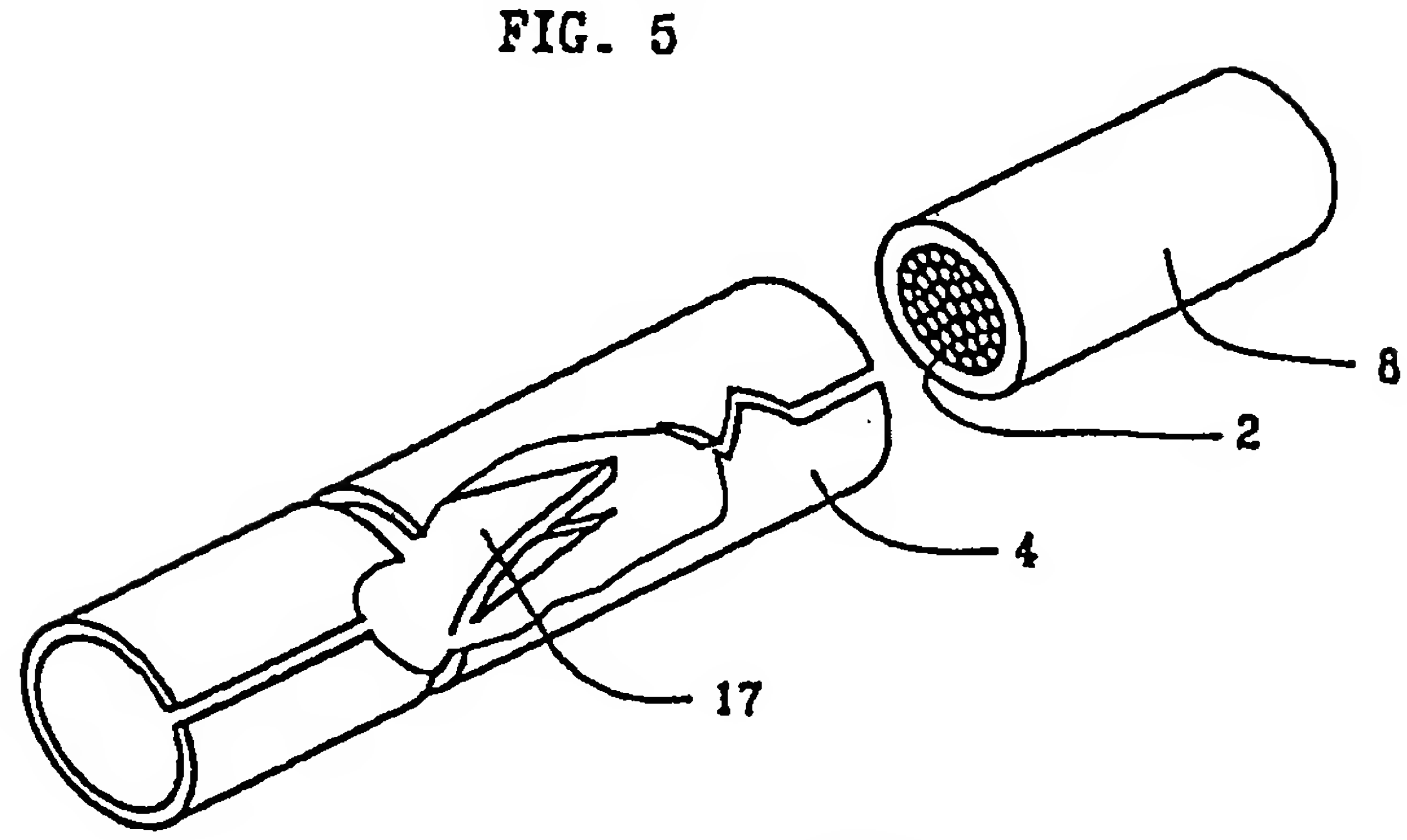

FIG.6

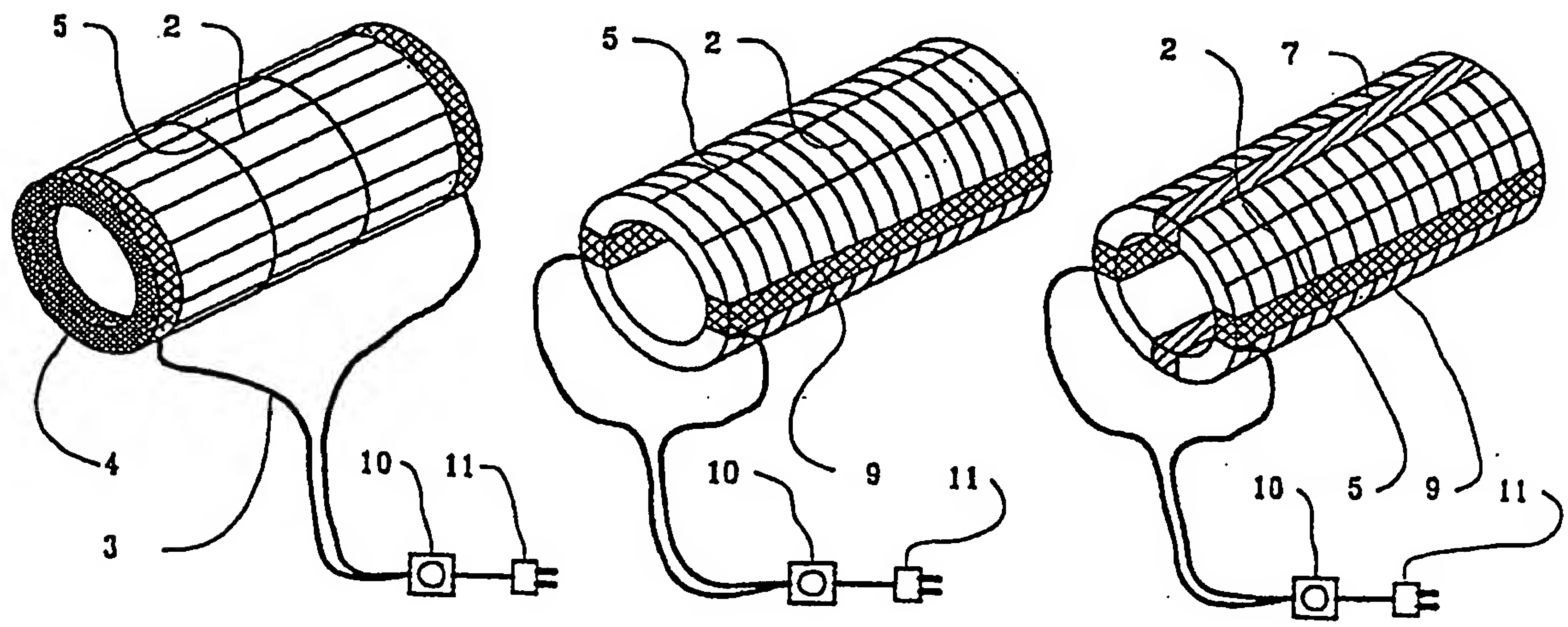

FIG. 7A FIG. 7B FIG. 7C

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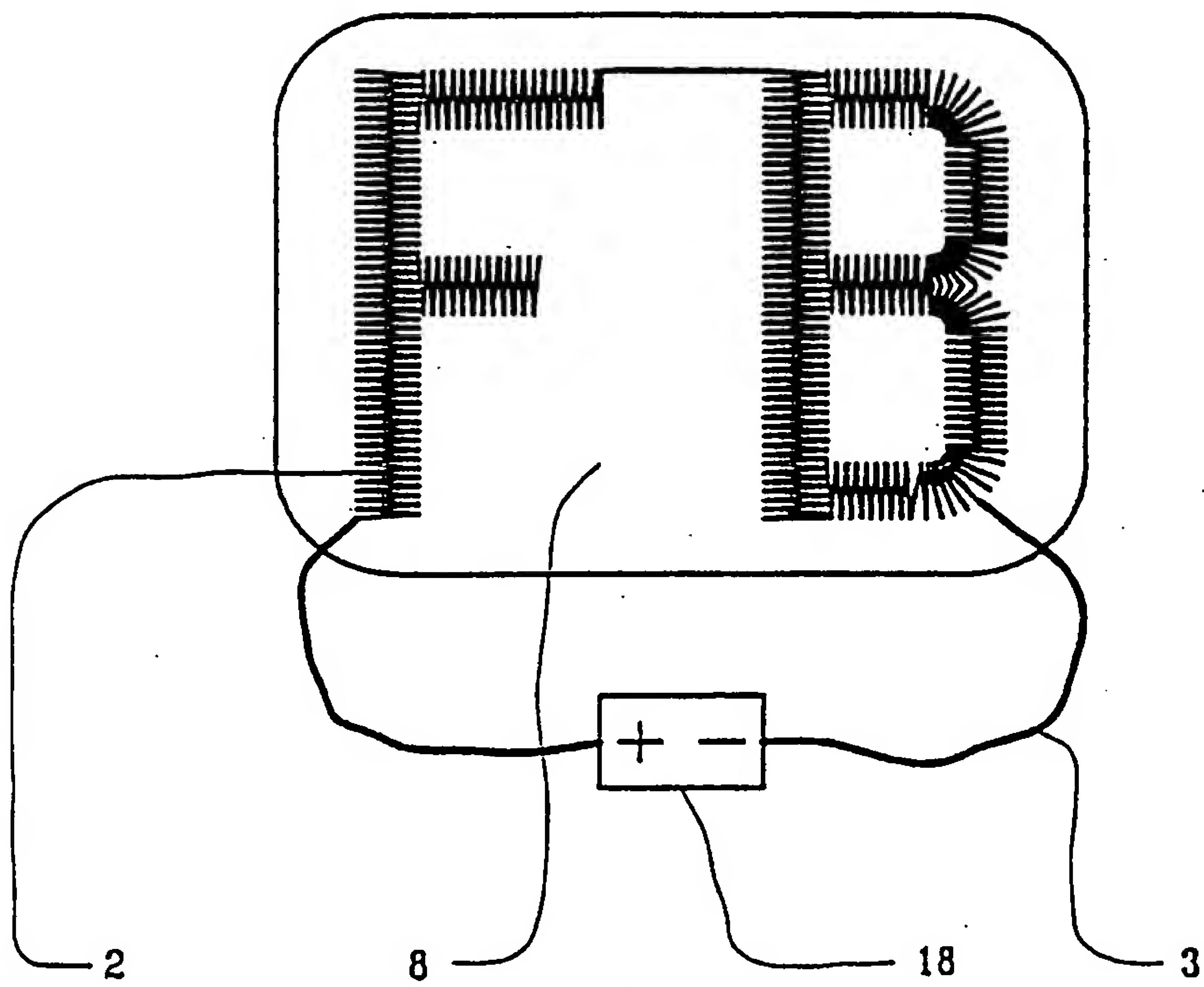


FIG. 8

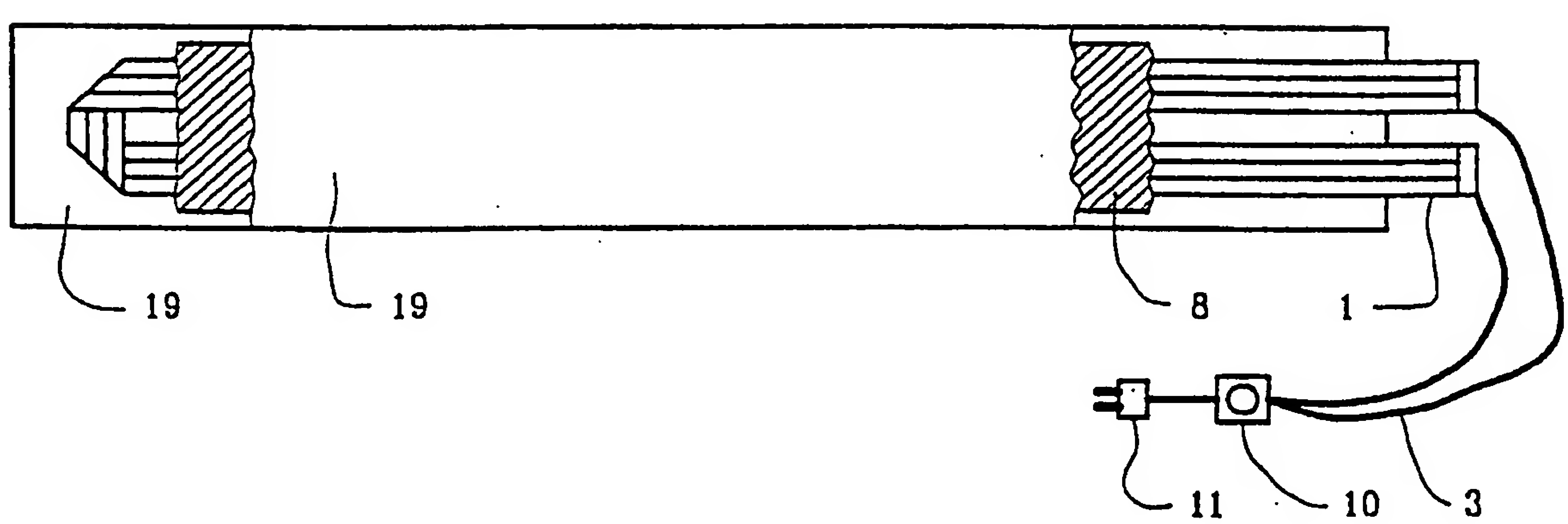


FIG. 9

Fig. 10A

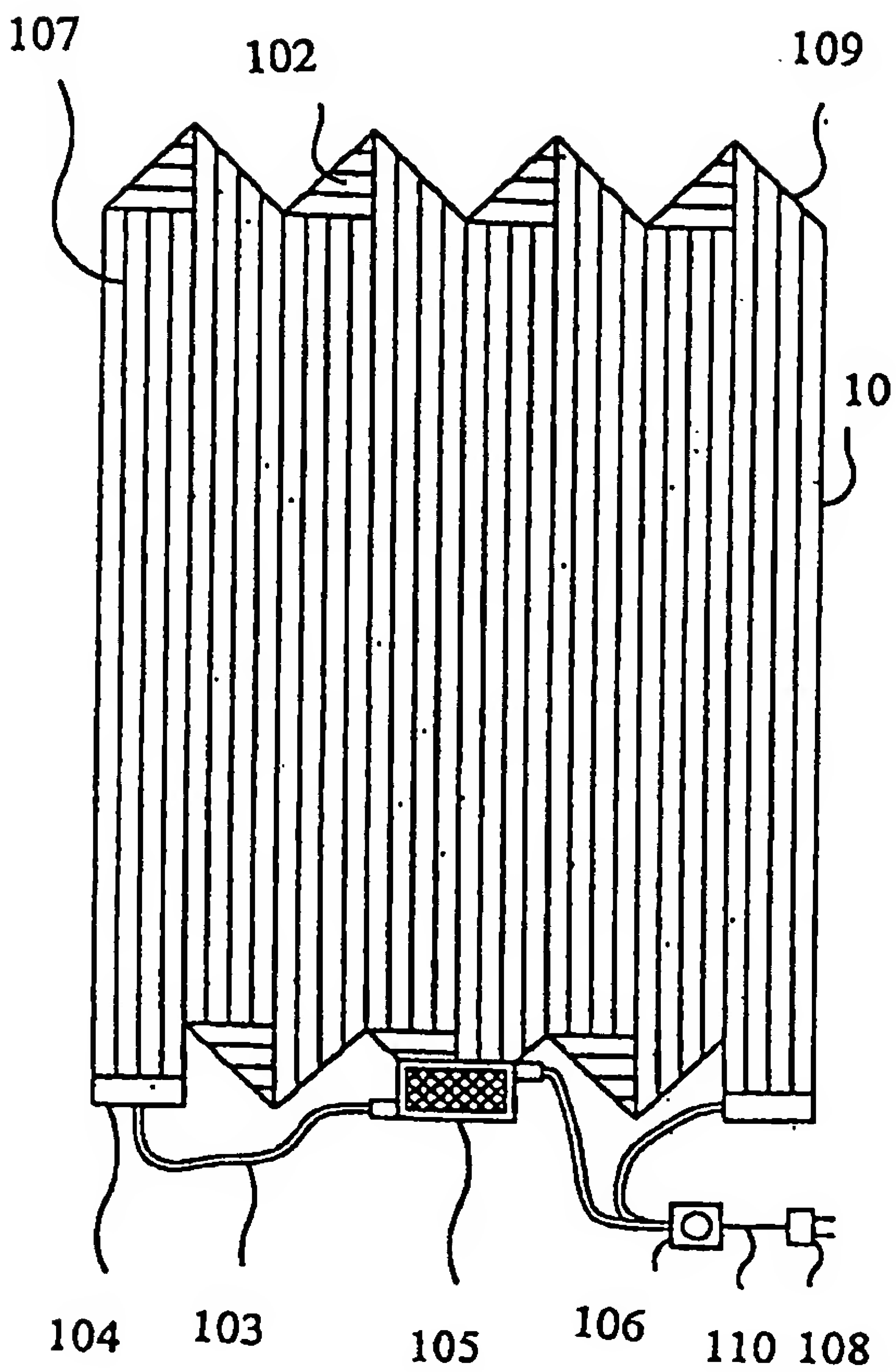


Fig. 10B

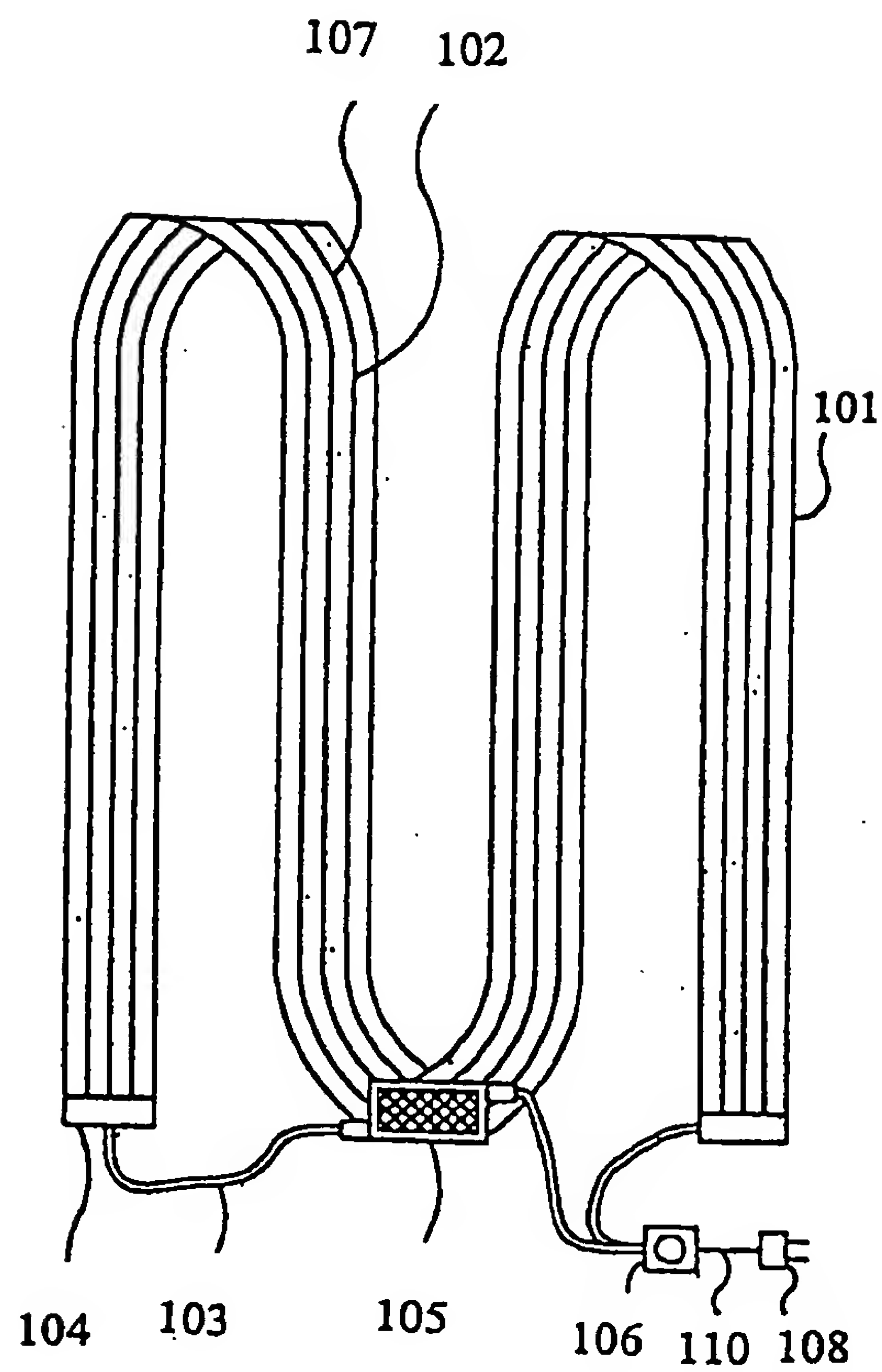


Fig. 11A

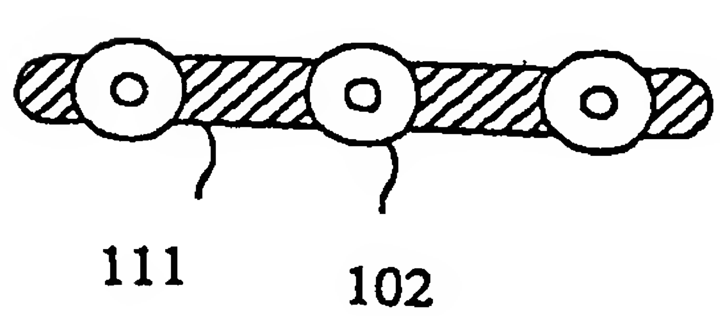


Fig. 11B

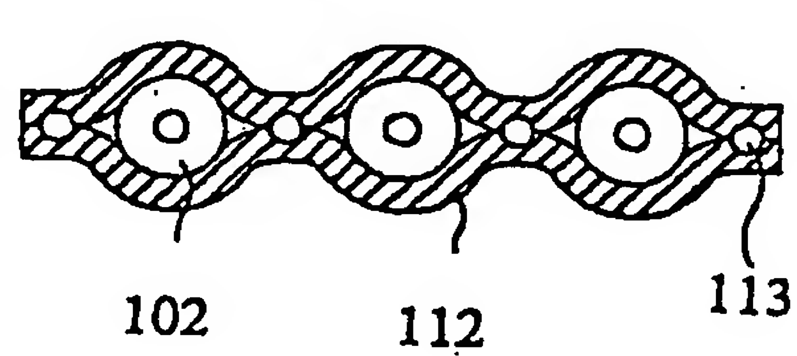


Fig. 11C

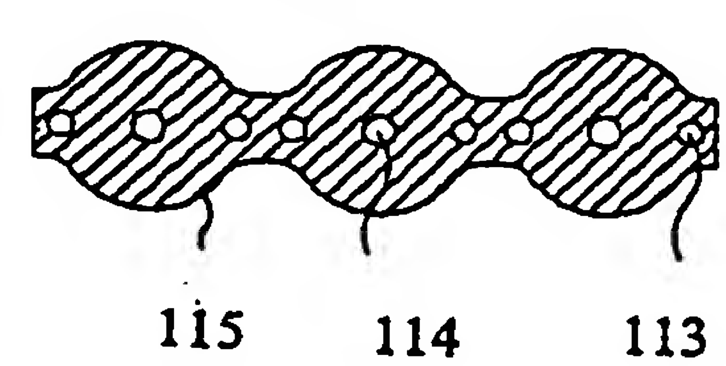


Fig. 12A

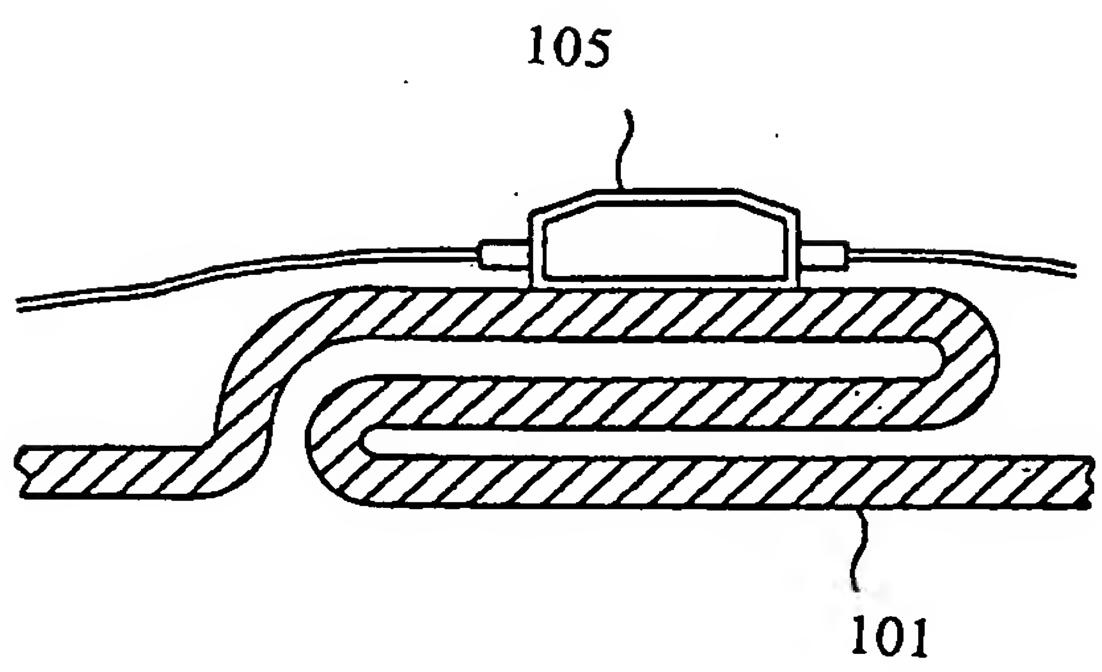


Fig. 12B

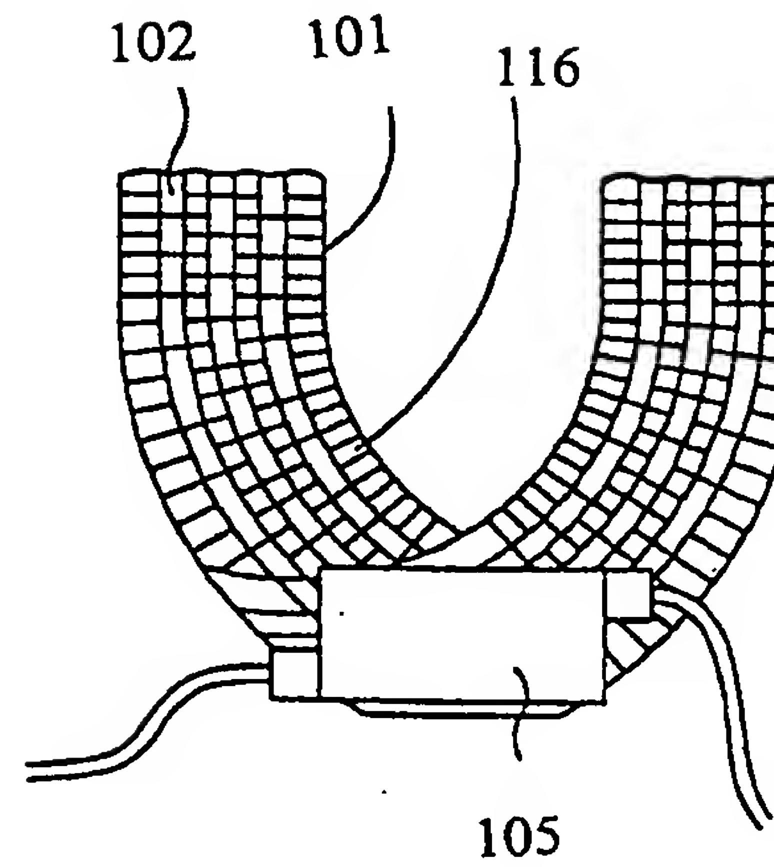


Fig. 13A

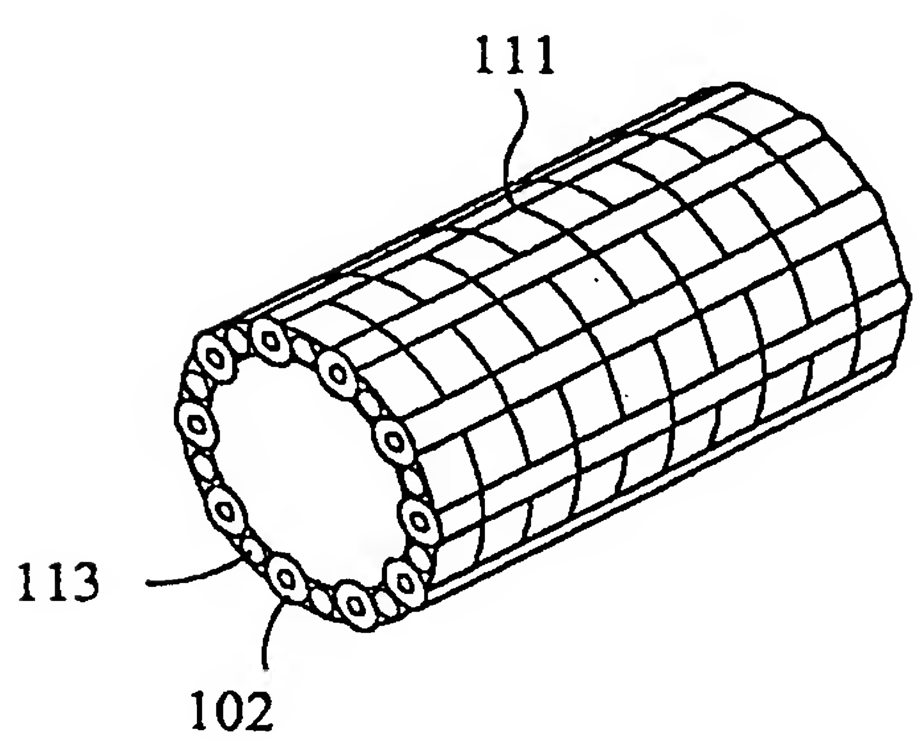
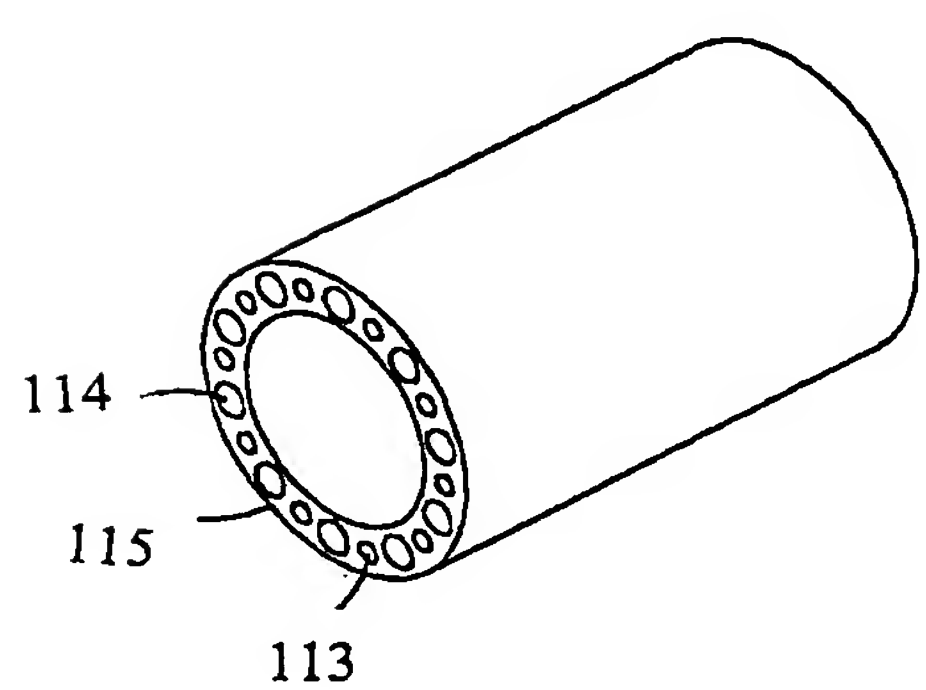


Fig. 13B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/22140

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H05B 3/34, 1/00, 3/10; H02H 5/04
US CL : 219/549, 548, 217, 529; 361/104
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/549, 548, 217; 361/104

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,309,596 A (CROWLEY) 05 January 1982, see entire document.	1-2, 4, 18
X	US 5,801,914 A (THRASH) 01 September 1998, see entire document.	1-50
X	US 5,111,025 (BARMA et al.) 05 May 1992, see entire document.	32
X	US 5,023,433 A (GORDON) 11 June 1991, see entire document.	34
A, P	US 5824,996 A (KOCHMAN et al.) 20 October 1998, see entire document.	1-68

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
07 DECEMBER 1999	21 JAN 2000

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